MASTER THESIS

SIMULATING THE EFFECT OF AN INTEGRATED EMERGENCY POST IN ENSCHEDE

Verification and application of a general and flexible discrete-event simulation model

D.M. Koster

Examination committee
M.A. Bruens, MSc
dr. ir. M.R.K. Mes
dr. ir. I.M.H. Vliegen

UNIVERSITY OF TWENTE.

SIMULATING THE EFFECT OF AN INTEGRATED EMERGENCY POST IN ENSCHEDE

Verification and application of a general and flexible discrete-event simulation model

SEPTEMBER 2014

Author
D.M. Koster, BSc
Industrial Engineering and Management
School of Management and Governance

External supervisor
M.A. Bruens, MSc
Acute Zorg Euregio

First internal supervisor
dr. ir. M.R.K. Mes
School of Management and Governance
Department IEBIS
University of Twente

Second internal supervisor
dr. ir. I.M.H. Vliegen
School of Management and Governance
Department IEBIS
University of Twente

Summary

Research motivation
In the Netherlands, it is possible to enter the emergency department (ED) without a referral from a general practitioner (GP). Due to this, many patients with a non-urgent demand for care register at the ED, which has a number of negative consequences. A possible solution for this is to form an integrated emergency post (IEP). This is an organizational model in which the general practitioners post (GP post) collaborates closely with the ED at the same location and with one common counter.

Currently, the ED of Medisch Spectrum Twente (MST) is not integrated with the local GP post, Huisartsendienst Twente-Oost (HDT-Oost). At the moment, MST is building a new hospital due to which there is a possibility to integrate the two organizations. However, they lack insight into the effect of integration on the patients, and on the processes that take place at the ED and the GP post.

Research objective
The objective of this research is twofold. The first objective is to gain insight into the effects of integrating the emergency department of MST and the GP Post of Enschede (HDT-Oost). This research especially focuses on logistical indicators of patient satisfaction (including length of stay). The second objective is to verify the general applicability of an existing discrete-event simulation framework for evaluating integrated emergency posts, that will be used in this research.

Method
The existing simulation model that will be used in this research to determine the effects of integration, is based on the IEP in Almelo. It is assumed that this model is general and flexible and that it can easily be adapted to other emergency departments. We verify this statement by using the simulation model in a different setting. Based on process and data analysis, we analyze the differences between the situation in Enschede and the situation in Almelo. Where necessary, we adjust the simulation model. After this, we will perform experiments to determine how an IEP can be organized in the most efficient way in Enschede.

Results
Table 1 shows the simulation results when moving from a non-integrated emergency post (NIP) to an integrated emergency post. Surprisingly, we see that the average length of stay (LOS) increases at both organizations.

Table 1
From a non-integrated emergency post to an integrated emergency post

	Non-integrated emergency post	**Integrated emergency post**	**Difference**	
	LOS (min)	*LOS (min)*	*Δ LOS***	*P-value*
ED	117.73	154.46	31.20%	0.000*
GP post	12.27	15.79	28.65%	0.000*

* Significant difference with α = 0.05; ** Δ LOS = difference in LOS between the experiments

Because stakeholders from both organizations are interested in how an IEP can be organized in the most efficient way, we composed several interventions that possibly contribute to a decrease in the average LOS of patients. These interventions are analyzed apart from each other. The interventions that have a significant, positive effect on the average LOS at (one of) the organizations in the separate analysis were: changing the division of labor (regarding the ED doctor), using a nurse practitioner (NP) at the GP post, adding an additional GP at the GP post, and the use of the same triage system. These interventions are combined to identify possible interaction effects. It appears that a combination of the interventions leads to a further decrease in the average LOS at both organizations (compared to the separate experiments). The outcome of the scenario that has the most potential to succeed is given in Table 2. This scenario is a combination of a changed division of labor, adding a NP at the GP post, and using the same triage system. If we compare this scenario to the NIP, it leads to a decrease in the LOS at the ED of 10.77%, and to a decrease in the LOS at the GP post of 19.71%.

Table 2
The best scenario compared to the NIP and the IEP

	Outcomes			**Difference**			
	NIP	**IEP**	**IEP +*** **	**NIP vs. IEP +**		**IEP vs. IEP +**	
	LOS (min)	*LOS (min)*	*LOS (min)*	*Δ LOS***	*P-value*	*Δ LOS***	*P-value*
ED	117.73	154.46	105.04	-10.77%	0.000*	-31.99%	0.000*
GP post	12.27	15.79	9.85	-19.71%	0.000*	-37.59%	0.000*

*Significant with α = 0.05;** Δ LOS = difference in LOS; *** IEP + = integrated emergency post + interventions

Conclusion

Integrating the emergency department of MST with the local GP post (HDT-Oost) yields no positive effects when stakeholders from the organizations are not prepared to implement some organizational changes. However, when the integration is associated with a number of organizational changes, integration will lead to significant, positive effects. The existing simulation model is used in the determination of these effects, after a number of adjustments and additions to the model were made.

Samenvatting

Aanleiding
In Nederland bestaat de mogelijkheid om zonder verwijzing naar de spoedeisende hulp (SEH) te gaan. Hierdoor melden veel patiënten met een niet-spoedeisende zorgvraag zich bij de SEH, wat negatieve consequenties heeft. Een mogelijke oplossing hiervoor is het vormen van een geïntegreerde spoedpost (IEP). Dit is een organisatiemodel waarbij de huisartsenpost (HAP) nauw samenwerkt met de SEH op dezelfde locatie, met één gemeenschappelijke balie.

Momenteel is de SEH van Medisch Spectrum Twente (MST) niet geïntegreerd met de lokale huisartsenpost, Huisartsendienst Twente-Oost (HDT-Oost). In de nieuwbouwplannen van MST bestaat de mogelijkheid om de twee organisaties te integreren. Echter, er mist inzicht in de effecten van een integratie op de patiënten en de processen die plaatsvinden op de huisartsenpost en de spoedeisende hulp.

Onderzoeksdoel
Het doel van dit onderzoek is tweeledig. Het eerste doel is om inzicht te verkrijgen in de effecten van integratie van de SEH van MST en de HAP Enschede van HDT-Oost. Hierbij wordt voornamelijk gekeken naar logistieke indicatoren voor patiënttevredenheid (waaronder doorlooptijd). Het tweede doel van dit onderzoek is het verifiëren van de generieke toepasbaarheid van een bestaand discrete-event simulatiemodel voor het evalueren van geïntegreerde spoedposten, dat gebruikt gaat worden in dit onderzoek.

Methode
Het bestaande simulatiemodel dat in dit onderzoek gebruikt gaat worden om de effecten van integratie te bepalen, is gebaseerd op de spoedpost in Almelo. Men veronderstelt dat dit model flexibel en generiek is en eenvoudig kan worden aangepast voor gebruik bij andere spoedposten. We verifiëren deze uitspraak door het simulatiemodel te gebruiken in een andere setting. Op basis van proces- en data analyse wordt gekeken waar de situatie in Enschede verschilt van de situatie in Almelo. Waar nodig wordt het simulatiemodel aangepast, waarna experimenten worden uitgevoerd om te bepalen hoe een geïntegreerde spoedpost het best kan worden ingericht in Enschede.

Resultaten
Tabel 3 geeft de resultaten weer wanneer wordt overgegaan van een niet-geïntegreerde spoedpost (NIP) naar een geïntegreerde spoedpost. Opmerkelijk is dat zowel de doorlooptijd voor de spoedeisende hulp, als ook de doorlooptijd voor huisartsenpost omhoog gaat bij integratie.

Tabel 3
Van een niet-geïntegreerde spoedpost naar een geïntegreerd spoedpost

	Niet geïntegreerde spoedpost	Geïntegreerde spoedpost	Verschil	
	DLT (min)	*DLT (min)*	*Δ DLT***	*P-waarde*
SEH	117,73	154,46	31,20%	0,000*
HAP	12,27	15,79	28,65%	0,000*

* significant verschil met α = 0,05; ** Δ DLT = verschil in doorlooptijd tussen de experimenten

Omdat belanghebbenden uit beide organisaties geïnteresseerd zijn in de wijze waarop een geïntegreerde spoedpost het best kan worden ingericht in Enschede, zijn er verschillende interventies opgesteld die mogelijk kunnen bijdragen aan een lagere doorlooptijd. Deze interventies zijn apart van elkaar geanalyseerd. De interventies die een significant, positief effect hebben op de gemiddelde doorlooptijd van (één van de) organisaties in de individuele analyse waren: het veranderen van de taakverdeling (m.b.t. de SEH-arts), het inzetten van een verpleegkundig specialist (VPS) op de HAP, het inzetten van een extra huisarts op de HAP en het gebruiken van hetzelfde triagesysteem. Deze interventies zijn gecombineerd om mogelijke interactie effecten te identificeren. Het blijkt dat een combinatie van de interventies leidt tot een verdere afname in de gemiddelde doorlooptijd van de organisaties (vergeleken met de afzonderlijke experimenten). De uitkomst van het scenario dat de meeste potentie heeft om te slagen is gegeven in Tabel 4. Dit scenario is een combinatie van het veranderen van de taakverdeling, het inzetten van een VPS op de HAP en het gebruiken van hetzelfde triagesysteem. Vergeleken met de NIP, leidt tot scenario tot een afname in de gemiddelde DLT op de SEH van 10,77% en tot een afname in de gemiddelde DLT op de HAP van 19,71%.

Tabel 4
Het beste scenario vergeleken met de NIP en de IEP

	Uitkomsten			**Verschil**			
	NIP	**IEP**	**IEP +*** **	**NIP vs. IEP +**		**IEP vs. IEP +**	
	DLT (min)	*DLT (min)*	*DLT (min)*	*Δ DLT***	*P-waarde*	*Δ DLT***	*P-waarde*
SEH	117,73	154,46	105,04	-10,77%	0,000*	-31,99%	0,000*
HAP	12,27	15,79	9,85	-19,71%	0,000*	-37,59%	0,000*

*Significant verschil met α = 0,05; ** Δ DLT = verschil in DLT; *** IEP + = geïntegreerde spoedpost + interventies

Conclusie

Integratie van de SEH van het MST en de lokale huisartsenpost (HDT-Oost) leidt niet tot positieve effecten als de belanghebbenden uit beide organisaties niet bereid zijn om een aantal extra veranderingen door te voeren in de organisatie. Wanneer integratie echter gepaard gaat met een aantal veranderingen binnen de organisaties zal het leiden tot significant positieve effecten. Het bestaande simulatiemodel is gebruikt bij de bepaling van de effecten, na enige aanpassingen en toevoegingen in het simulatiemodel.

List of abbreviations and definitions

DES	Discrete-event simulation
EC	Entrance complaint; complaint of the patient that is registered when the patient enters the ED.
ED	Emergency department
ED self-referrals	Patients who enter the ED without a referral
Existing simulation model	The simulation model that is used at the integrated emergency post in Almelo
GP	General practitioner
GP post	General practitioners post
HDT-Oost	Huisartsendienst Twente-Oost; a collaborating organization between general practitioners in Enschede and the surrounding areas, which provide out-of-hours urgent primary care.
IEP	Integrated emergency post
Labeled patient	A patient that is referred to a given specialism at the emergency department by a general practitioner (working at the GP post) or by an internal or external specialist.
LOS	Length of stay; the time between the arrival of the patient and the departure of the patient.
MST	Medisch Spectrum Twente; a level 1 trauma center located in the Netherlands.
New simulation model	The simulation model that will be used in the analysis of Enschede.
NIP	Non-integrated emergency post
NP	Nurse practitioner; staff type at the GP post.
Out-of-hours care	Care delivered from 5 pm to 8 am on workdays, from 5 pm on Friday to 8 am on Monday, and on national holidays.
Primary care	Accessible care for which a patient does not need a referral.

Secondary care	Care for which a patient generally needs a referral by another health care professional
Triage	Process in which the urgency of the patient in determined
Unlabeled patient	A patient that is not referred to (a given specialism at) the emergency department. An unlabeled patient is a self-referral or a patient that is brought to the emergency department by ambulance, helicopter, or by the police.

Table of contents

Preface

Well, here it is, my final master thesis! The end product of seven months of research, but also the last piece for achieving my master's degree in Industrial Engineering and Management at the University of Twente. The completion of this study, will also be the end of my 5-year study period.

Before I started studying, I wanted to do "something" in the health care sector. What this had to be exactly, I did not knew at that moment. After high school, I started studying Health Sciences. During this bachelor, I was introduced to health care logistics. I found this very interesting and this was the reason why I decided to do a master in Industrial Engineering and Management. In this study, I learned a lot about analyzing processes, finding bottlenecks, and optimizing processes in the health care sector. These are things that are, in my opinion, very interesting and at this moment I am pretty sure that I have found my "something" in the health care sector.

During lectures of the course *simulation*, which is part of the masters' program, we have heard about a simulation model that was developed for the integrated emergency post in Almelo. At that moment, I found that subject very interesting. Therefore, I appointed my interests in simulation and in (acute) care in my search for a nice and challenging subject for my master thesis. Already soon, the subject "integration emergency department and GP post" was suggested to me. And now, nine months after applying for this subject, I completed the research.

I could not have performed this research without the help of some people, for which I would like to thank them. First, I thank Manon Bruens for the daily supervision and for answering all my questions. Second, I thank my supervisors from the University of Twente, Martijn Mes and Ingrid Vliegen, for the positive feedback during the execution of my research. Third, I thank the people involved from the ED and the GP post for the large amount of information that was needed as input for my research. Last, but definitely not least, I thank all the colleagues from Acute Zorg Euregio. I am convinced that the friendly and helpful working atmosphere had a positive effect on the results of this research.

I hope you will all enjoy reading this research.

Margo Koster
Enschede, September 2014

1 Introduction

Well-organized out-of-hours care is important for a properly functioning health care system. People all over the world are concerned with the quality, efficiency, and accessibility of it. The organization of out-of-hours care changed significantly during the last years. This thesis focuses on recent changes in the organization of out-of-hours care, and especially on the effects of integration of the emergency department of the hospital “Medisch Spectrum Twente” and the general practitioners post “Huisartsendienst Twente-Oost”.

This chapter is structured as follows. Section 1.1 gives a short background on the subject of this thesis. Section 1.2 describes the setting in which this research takes place. Sections 1.3 and 1.4 describe, respectively, the problem statement and the objective of the research. In Section 1.5 the research questions are formulated, after which the research approach is described in Section 1.6. This chapter ends with a description of the scope of this research in Section 1.7.

1.1 Background

During the last years, the organization of out-of-hours medical care has substantially changed in many countries. In the Netherlands, out-of-hours care is defined as care delivered from 5 pm to 8 am on workdays, from 5 pm on Friday to 8 am on Monday, and on national holidays (Grol, Giesen & Uden, 2006). Formerly, out-of-hours primary care was organized in small groups of general practitioners (GPs), who joined a rotating system. Around the year 2000, these small groups transitioned into large scale cooperatives of GPs, which we denote by a general practitioners post (GP post). These cooperatives vary with respect to the service area, the number of participating GPs, accessibility, and the distance from a hospitals’ emergency department (Uden et al., 2006; Giesen et al., 2006).

In the Dutch health care system, a patient who needs out-of-hours care has three options. One could either contact the (large scale) GP post, go to the hospitals’ emergency department (ED), or call the emergency number (112). In the Dutch health care system, the GP acts as gatekeeper to secondary care; patients need a referral from their GP in order to make use of hospital services. However, to attend an ED, a referral is recommended but not strictly needed. It appears that due to this, some patients skip the GP and directly go to the ED (Uden, Winkens, Wesseling, Crebolder & Schayk, 2003). This causes a shift from primary to secondary care, which has a number of negative consequences: confusion among patients, patients with non-urgent acute care at the ED, and cost-ineffectiveness in the delivery of out-of-hours care.

Patients who need out-of-hours care are often confused where to go (Moll van Charante & Bindels, 2008). A cause of this confusion is that the primary tasks of the ED and the GP post are insufficiently defined and non-transparent. The confusion of the patient causes inefficiency in the delivery chain of out-of-hours care, because the patient is not always seen at the right place and by the right health care provider in terms of efficiency. In the Netherlands, but also in other countries, there are a lot of patients who directly go to the ED without first contacting the GP, the so called self-referrals. The percentage of self-referrals at the ED varies per hospital and increases as urbanization increases. Most of these self-referrals have a health care problem that could have been solved by a GP. The literature shows that this percentage is between 60 and 80% (Giesbers, Smits & Giesen, 2011; Klink, 2008). This leads to overcrowding at the ED and may lead to a decrease in the quality of care for more urgent cases (Moll van Charante & Bindels, 2008; Kool, Homberg & Kamphuis, 2008). The large number of self-referrals that wrongly utilize the expensive and specialized care offered at the ED leads to cost ineffectiveness in the emergency care. In addition, the providers of emergency care overlap each other, which lead to insufficient coherence and effectiveness in the emergency care.

1.2 Project initiators

This project is initiated by two organizations: 'Medisch spectrum Twente' (MST) and 'Huisartsendienst Twente-Oost' (HDT-Oost). This section outlines some key figures of both organizations.

MST

Medisch Spectrum Twente (MST) is one of the largest non-university hospitals in the Netherlands, and its core mission is promoting health of the people in the region. Basic care is the foundation of the delivered care, but MST also employs professionals with specialized knowledge/skills and has a number of special facilities for diagnosis and treatment (top clinical profile). Currently, the hospital consists of two hospital locations (Enschede & Oldenzaal) and two outpatient clinics (Haaksbergen & Losser), from which approximately 264,000 citizens are served. More key figures of MST are given in Table 5. MST is a level 1 trauma center, which means that it offers emergency care, multidisciplinary intensive care, and a wide range of specialisms 24 hours a day. The ED of MST treated 26,188 patients in the year 2013. Of these patients, 251 had a severe trauma. A patient is classified as a severe trauma when they had an Injury Severity Score (ISS) higher than 15 and were longer than two days admitted to the hospital, or died at the ED.

Table 5
Key figures MST (MST, 2012a; MST, 2012b; MST, 2013a; MST, 2013b)

	2012	**2013**
Turnover	€ 347,567,237	€ 359,302,000
Service area	264,000 citizens	264,000 citizens
Bed capacity	1070	1070
Staff employed, without medical specialists	2,668 FTE	2,669 FTE
Medical specialists, hiring & professionals	242 FTE	232 FTE
Outpatient visit	521,000	468,000
Day admissions	35,000	33,000
Clinical admissions	34,000	31,000
Nursing days	179,000	166,000

HDT-Oost

Huisartsendienst Twente-Oost (HDT-Oost) is a collaborating organization between GPs from Enschede and the surrounding areas. This organization consists of two GP posts, located in Enschede and Oldenzaal. The GP posts were created to help people with a need of out-of-hours care. HDT-Oost takes over the tasks of 116 GPs from the area outside office hours and has a service area of approximately 269,200 citizens (2013). Some key figures of HDT-Oost are given in Table 6.

Table 6
Key figures HDT-Oost (HDT-Oost, 2012; HDT-Oost, 2013)

	2012	**2013**
Service area	280,180 citizens	269,200 citizens
GPs	116	113
Triage assistants	40	41
Consults	72,964	70,594

1.3 Research motivation

Currently, there is a debate in the Netherlands on how to organize out-of-hours care and on the position and the role of GP cooperatives in the provision of out-of-hours care. The debate is strengthened by the desire to identify existing bottlenecks and to eliminate them (Uden, et al., 2006; NVZ, 2013). The main focus of the debate is on how to deal with the high number of self-referrals at EDs.

A possible solution to reduce the number of self-referrals at the ED, is to introduce payments for self-referrals with a need of primary care at the ED. Research has shown that this is an effective method. However, there is a possibility that self-referrals are deterred by payments in such a way, that they decide not to go to the ED even in acute or life-threatening cases (Reitsma & Jong, 2010). In addition, the Dutch minister of health states that such payments are undesirable. According to article 14, paragraph 2 of the Health Insurance Act, the care delivered at the ED is only reimbursed if it concerns acute care. So, officially primary (non-acute) care at the ED is not reimbursed, which makes it impossible to introduce payment for this kind of care. If one would like to introduce such a payment, primary care for self-referrals at the ED should be classified as insured care, by changing the Health Insurance Act. This is undesirable, because it means an extension of the basic package with unnecessary care (Schippers, 2013).

Another solution to reduce the number of self-referrals with a need of primary care at the ED, is by forming an integrated emergency post (IEP). This is an organizational model in which the GP collaborates closely with the ED at the same site. Such an IEP has several expected advantages, it would lead to: (i) a shift from secondary to primary care, (ii) a more efficient deployment of people and resources in the delivery of out-of-hours care, (iii) a higher employee satisfaction, (iv) an increased continuity of care through better coordination between health care providers, and (v) a higher patient satisfaction (Giesen, 2007). Kool, Homberg & Kamphuis (2008) filled this list with another expectation, namely a decrease in waiting-/ consultation times. Research shows that the introduction of such an organizational model does indeed have a positive effect on (some of these) factors (Kool, Homberg & Kamphuis, 2008; ZonMw, 2013). Due to the high number of positive effects of integration, this organizational model has many proponents, including the Dutch minister of health, the government, and many health care insurers. Many hospitals are currently thinking about integrating their ED with the local GP post.

At the moment, the ED of the hospital MST is not integrated with the local GP post (HDT-Oost). However, MST is building a new hospital next to the existing hospital and there is a possibility to integrate these two organizations, because the GP post is then directly adjacent to the ED. Stakeholders from both organizations expect that through this integration the out-of-hours care can be provided in a more efficient way. However, they lack insight into the effects of integration on the patients, and on the processes that take place at the ED and the GP post. Therefore, they want to gain insight in the quantitative effects of integration on logistical indicators for patient satisfaction, and on indicators for organizational efficiency, before they take a decision whether to integrate or not.

1.4 Objective

The objective of this research is **to gain insight into the effects of integrating the emergency department of MST and the GP Post located in Enschede** (HDT-Oost). This research especially focuses on the effects of integration on the patients, and on the processes that take place at the ED and the GP post. The results of this research contributes to the decision whether the ED of MST and HDT-Oost should integrate or not. Besides, it contributes to the knowledge on how acute care in Enschede can be organized in a more efficient way. Due to this, this research has a high societal relevance.

In addition to the societal relevance, this research is also scientifically relevant. In this research, the second objective **is to verify the general applicability of an existing discrete-event simulation framework for evaluating integrated emergency posts**. In collaboration with the general hospital "Ziekenhuisgroep Twente" (ZGT) and the GP post "Centrale Huisartsenpost Almelo" (CHPA), University of Twente performed a research with the topic: "Optimal logistics and patient preferences in emergency care: the GP post and the emergency department in one integrated emergency post". This research was funded by ZonMw, and focused on the effects of integration and how to optimally design an integrated emergency post, when taking into account patient preferences. Several theses and articles emerged from this large-scale study. One of the articles presents a general and flexible simulation model of the emergency department. Mes & Bruens (2012) state that this model can be adapted to other emergency departments as well as to other departments within a hospital. We verify this statement by using the simulation model in the urban area of Enschede, instead of the rural area of Almelo. If we need to make adjustments to the model, we try to keep these adjustments as generic as possible, such that the model is more broadly applicable.

1.5 Research questions

The main research question of this study is:

"What is the effect of integrating the general practitioners post of Enschede with the emergency department of MST, and in which way can the existing simulation model be used to correctly model the delivery of out-of-hours care in Enschede and to determine the effects of integration?"

To answer the main research question, we compose seven sub questions:

1. What is known in literature about simulation, simulation in health care, out-of-hours care, and simulation of out-of-hours care?

2. How is the current delivery of out-of-hours care in Enschede organized and how can it be modeled?

3. What are the changes that occur when the emergency department of MST integrates with the local GP post and how can we model this situation?

4. What changes need to be made in the existing simulation model in order to correctly simulate the organization of out-of-hours care in Enschede?

5. On the basis of which performance indicators can the integrated model be compared with the non-integrated model?

6. What are the expected effects when integrating the emergency department of MST with the local GP post?

7. How can we efficiently organize the integrated emergency post in Enschede and how robust are these effects?

1.6 Research approach

This study analyses the expected effects of integrating the ED of MST with the local GP post (HDT-Oost), by making use of discrete-event simulation. The model described by Mes and Bruens (2012) serves as basis of this research. The conceptual model, developed for analysis of the IEP in Almelo, will be compared with the situation of Enschede and, if necessary, modified to make it usable for this research. We will examine the models' robustness and generalizability and we make adjustments to the model where necessary.

The structure of this thesis is based on the 10-step approach of a simulation study as proposed by Law (2007). This approach is extended with a literature review, in order to make the 10-step approach applicable to this research. In addition, we defined the steps of Law in a different way, such that it matches with the proposed sub questions. The plan of approach is given in Figure 1.

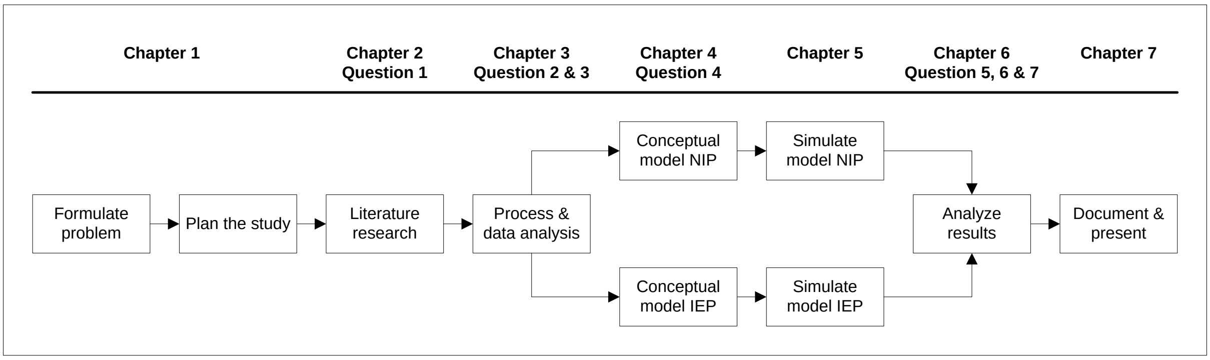


Figure 1
Plan of approach

Data gathering & analysis

We perform a literature study to obtain relevant background knowledge on the subject of this research. The literature study starts with a top down strategy, in which we use several, well-defined search terms in several search engines. In order to obtain more relevant results, we use the bottom up strategy, in which we use the referenced and cited articles.

We obtain the information required for this research through process analysis and data analysis. Process analysis is performed by conducting stakeholder interviews and by performing observational research (and through the previous described literature study). Process analysis will be used for two purposes. First, to model the delivery of out-of-hours care in Enschede before integration. Second, to map the changes that occur through integration in order to model the situation after integration. Stakeholder interviews are also used to determine the key performance indicators which can be used to compare the non-integrated emergency post (NIP) and the IEP in Enschede. The quantitative data required for this research will be obtained from the hospital information system, and will be used as input for the simulation model as well as for validation. We use Microsoft Excel 2013 for the basic data analysis. For more advanced, statistical analysis of the data we use the program Minitab. This program is chosen because of its ease of use. The simulation of this research will be performed in discrete-event simulation software package Tecnomatix Plant Simulation version 10.1. This is the program in which the existing simulation model has been implemented.

1.7 Scope

In order to obtain focus in this study, it is important to introduce some restrictions and limitations. This study limits itself to modeling the processes at the ED and the GP post in Enschede. In the Section 1.2, it is described that the hospital MST consists of two hospitals, and two outpatient clinics. In this study we will only focus on the ED of the location Haaksbergerstraat in Enschede. The considered GP post is also located at this location.

Various processes in the hospital, but also outside the hospital, affect the course of events at the ED/ GP post. However, it is impossible to model all these processes. It would not fit within the given time frame, and the study will lose its focus. So, only the processes that actually take place at the emergency department/ GP post will be taken into account.

The effects that are going to be determined by this research, limit themselves to the effects on the patients, and on the processes that take place at the ED and the GP post. We will primarily focus on logistical indicators for patient satisfaction, and on indicators for organizational efficiency. Determining the financial effects of integration falls outside the boundaries of this research.

2 Theoretical framework

This chapter describes what is already known in literature about integrated emergency posts, simulation, and simulation of integrated emergency posts. It functions as a scientific foundation for this research. Section 2.1 describes the definition of simulation, and how and why it is used. Section 2.2 and 2.3 describe, respectively, studies in the field of simulation in health care and studies in the field of simulation of EDs. Section 2.4 gives a description of integrated emergency posts. Section 2.5 gives a description of general and flexible simulation frameworks. We end this chapter with our contribution to the literature in Section 2.6.

2.1 Simulation

Simulation is a computerized technique in which one imitates operations of various kinds of real-world facilities or processes. According to Law (2007), simulation can be defined as: "*the creation of a model that represents a system, and using this model to better understand the system it represents.*" Shannon (1998) defines simulation as: "*the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system*."

Key components in both definitions of simulation are the words system and model. The studied facility or process in a simulation study is called a system. In order to scientifically study such a system, one have to make a set of assumptions about the working of the system. These assumptions constitute a model that is used to try to gain understanding of the studied system (Law, 2007).

There are more possible ways to explore a system, see Figure 2. First of all, one could experiment with the actual system. However, such experiments might be too costly or disruptive to a system. In addition, it is also possible that the system does not exist, but one might want to study the effect of a certain system or intervention in order to answer the question whether to build the system or not. For these reasons, it is desirable to make use of a model of the system. Then we could choose whether to build a physical model or a mathematical model. Most of the models build for engineering or management systems are mathematical models that represent a system in terms of logical and quantitative relationships. Such models are preferably solved in an analytical way. However, this is only possible when an analytical solution is available and can be computed efficiently. When this is not possible, the system must be studied by means of simulation (Law, 2007).

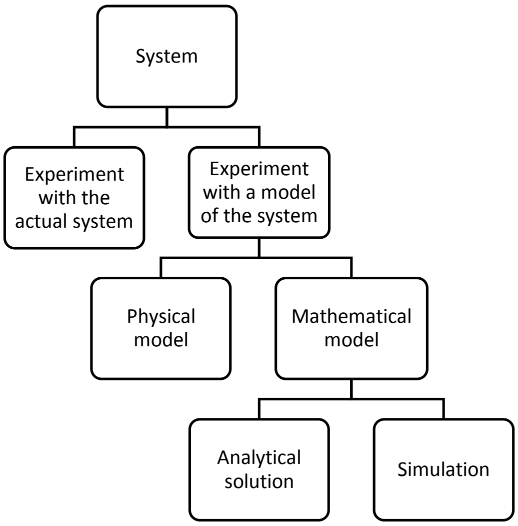


Figure 2
Ways to study a system (Law, 2007)

Simulation models can be classified along three different dimensions. The first dimension is whether the simulation model is static or dynamic. A static simulation model is a representation of a system at a particular time, or one in which time plays no role. A dynamic simulation model represents a system as it changes in time. The second dimension is whether the model is deterministic or stochastic. A deterministic model is a model in which the components are predictable or which does not contain any probabilistic components. Stochastic models are models in which there are at least some random components. The third dimension is whether the simulation model is continuous or discrete. In a continuous model the state variables change continuously with respect to time. In a discrete model, the state variables change at separated points in time (Law, 2007).

Simulation modeling has several advantages. For some complex systems, an analytical mathematical model is infeasible, due to which simulation is the only possible method to use (Law, 2007). In addition, simulation models are easier to understand and to justify to management than analytical models (Shannon, 1998). Further, simulation enables us to estimate the performance of an existing system under specific operating conditions. Besides, it can be used to answer 'what if' questions, by experimenting with a new and unfamiliar system, or by comparing different proposed system designs. In these estimations and comparisons, the experimental conditions can be much better controlled than by making use of the actual system. The last advantage that we point out is that simulation allows us to control time. A system can be studied for several months or years in compressed time, or the detailed working of a system can be studied in expanded time (Law, 2007; Shannon, 1998).

The use of simulation also has some disadvantages. First, the investment required to set up a simulation study is high. It is expensive and time-consuming to develop a simulation model, and it requires specialized training. Second, due to the stochastic nature of the study, it will only provide estimates of the actual system. Therefore, these kind of studies are better in comparing alternative system designs than they are at optimization. The third disadvantage is that gathering reliable input data is sometimes difficult. This issue and the large volume of quantitative data produces by a simulation study often creates a tendency to put more confidence in the study results than is justified (Law, 2007; Shannon, 1998).

Steps in a simulation study

A sound simulation study consists of ten steps, which are represented in Appendix A. This 10-step approach is proposed by Law (2007). Other authors propose a different way of performing a simulation study. Banks & Carson (1988) add an eleventh step to the process, the implementation step. They state that this step is very sensitive to the involvement of the end user in the whole simulation process. Brailsford, Harper, Patel & Pitt (2009) state that the implementation of simulation models in health care operations research are still low. Eldabi & Paul (2001) have some critics on the existing modeling approaches. First, the approaches give too little attention to problem formulation, while this is the most important stage for problem understanding. Second, they state that data of health care systems is not reliable enough to serve as basis for a model. They proposed a Modeling Approach that is Participatory Iterative for Understanding (MAPIU). This approach is based on participatory modeling where stakeholders are involved in the complete modeling processes in an iterative way.

All authors describe two feedback loops: verification and validation. In the verification process, one determines whether the assumptions document has been correctly translated into a computer program (Law, 2007). Law describes several techniques to verify a simulation computer model. The described techniques are: 1) write and debug the program in modules, 2) review of the program by more persons, 3) run the simulation under a variety of settings of the input parameters, 4) design a trace, allowing a comparison between the state of the simulated model with hand calculations to see whether the program is working as intended, 5) run the model under simplifying assumptions, 6) observe an animation of the simulation output, 7) compute the sample mean and sample variance for each simulation input probability distribution and compare them with the desired mean and variance, and 8) use a commercial simulation package to reduce the amount of programming required.

In the validation process, one determines whether a simulation model is an accurate representation of the system, for the particular objectives of the study (Law, 2007). Law describes several techniques which can be used for increasing the validity and credibility of a simulation model. These techniques are: 1) collect high-quality information and data on the system, 2) interact with the manager of a regular basis, 3) maintain a written assumptions document and perform a structured walk-through, 4) validate components of the model by using quantitative techniques, 5) validate the output from the overall simulation model, and 6) animation.

Besides the steps of validation and verification, there is also a process of establishing credibility. A model has credibility if the manager and other stakeholders accept it as correct (Law, 2007). Figure 3 shows the timing and the relationship between the steps proposed by Law and different processes.

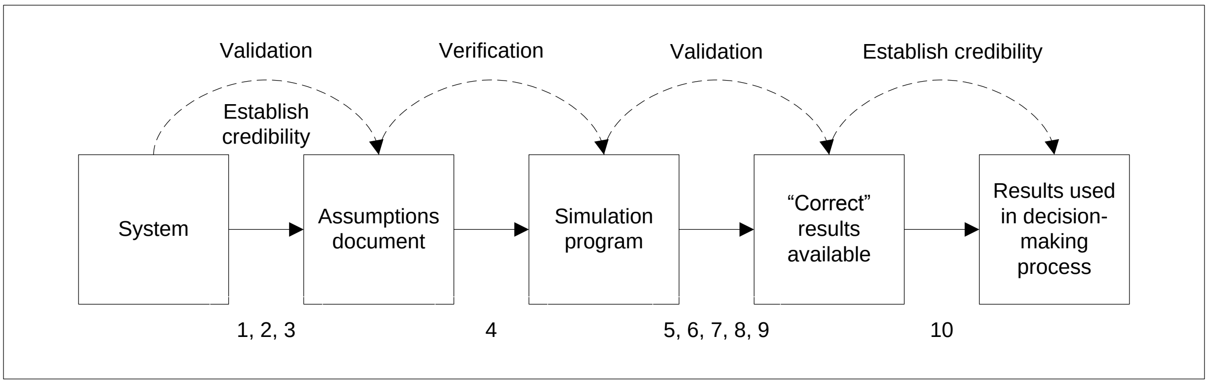


Figure 3
Timing and relationship validation, verification, and credibility (Law, 2007)

2.2 Simulation in health care

Simulation is a widely accepted and powerful tool and is already applied in a variety of fields, such as manufacturing, military, and logistics. The application of simulation showed great potential to be accepted in health care facilities, which can also be seen from the significantly increased number of publications in the area of simulation in health care (Mustafee, Katsaliaki & Taylor, 2010; Fone et al., 2003). Literature reviews on the use of simulation in health care are published by the previously referred authors Mustafee et al. (2010) and Fone et al. (2003), and by Brailsford, Harper, Patel & Pitt (2009) and Mielczarek & Uzialko-Mydlikowska (2012). Brailsford et al. (2009) and Fone et al. (2003) took a wider view on modeling in health care and included also other modeling techniques than simulation. The reviews of Mustafee et al. (2010) and Mielczarek and Uzialko-Mydlikowska (2012) focused only on simulation modeling in health care.

Mustafee, Katsaliaki & Taylor (2010) have performed a literature study of the most relevant articles published in the area of health care simulation. They identified four simulation techniques commonly used for simulation in health care, which we will explain shortly. The first technique is Monte Carlo simulation (MCS). This is a statistical technique that generates a value from a sequence of random numbers from a known probability distribution. This simulation technique is commonly used when it is impossible to calculate exact results by making use of fixed values or deterministic algorithms. The second technique is discrete-event simulation (DES). According to Law (2007), discrete-event simulation: "*concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time."* DES is commonly used to model queuing systems. The third technique is system dynamics (SD), this is a modeling approach with a holistic system perspective that analyzes the behavior of a complex system over time. The fourth technique is agent-based simulation (ABS), which adopts a bottom-up approach by focusing on writing instructions that specify the behavior of the agents that make-up the real-world system, such that the actual system behavior arises as a results of the interactions of individual agents. These techniques are also mentioned by Brailsford, Harper, Patel & Pitt (2009) and Mielczarek & Uzialko-Mydlikowska (2012) as the most commonly used simulation techniques.

The simulation technique that is used in this research is discrete-event simulation. Also on this specific topic, there are a lot of literature reviews available. Examples of these are: Jacobson, Hall & Swisher (2006); Jun, Jacobson & Swisher (1999); Gunal & Pidd (2010); and Thorwarth & Arisha (2009). The most frequently described study objective areas of simulation in health care are patient flow and resource allocation. The former includes scheduling of patients and admissions, patient routing and flow schemes, and scheduling and availability of resources. The latter includes bed sizing, room sizing, staff sizing, and the planning of those resources (Jun, Jacobson & Swisher, 1999). The application areas of these kind of simulation studies are: 1) epidemiology, 2) health and care systems operation, 3) health and care systems design, 4) medical decision making, and 5) extreme events planning (Mielczarek & Uzialko-Mydlikowska, 2012).

2.3 Simulation of emergency departments

Discrete-event simulation is also often applied to simulate EDs. The objective areas on which these studies focus can be roughly classified into the two areas of the previous section. An example on the topic of patient flow is the study of Rossetti, Trzcinski & Syverud (1999), in which they analyzed how staffing at lower time of the day/week can be reduced to save expenditures and to increase staff utilization. Garcia, Centeno, Rivera & DeCario (1995) analyzed how to reduce the waiting times of low urgent patients. They concluded that the waiting times for those patients could be reduced by 25% by making use of a fast-track lane. Another, more recent example is the study of Wang, Li & Tussey (2012), they used simulation in order to analyze the patient flow and to determine the bottlenecks in reducing the length of stay of the patients. Abo-Hamad & Arisha (2013) performed a simulation study in which they analyzed the effect of several factors on patient throughput and ED efficiency. An example on the topic of resource allocation is the study of Komashie & Mousavi (2005), in which they experimented with several scenarios of varying the number of beds and the number of doctors.

Hay, Valentin & Bijlsma (2006) stated that most of the operational research performed at the ED took a factory view of a hospital. However, they discovered that this way of thinking can lead to incorrect results. By making use of a factory view, the entities join a queue with a certain priority. This queue is often processed by priority (or due date). However, when the number of resources are inadequate, some entities will be processed after their due date. This is not possible in an ED, because patients with a low priority cannot wait interminably for treatment. By making use of the conventional approach at the ED, patients with a high priority are always treated first. Due to this, low priority patients will be treated either outside the allowable time frame or not at all.

2.4 Integrated emergency posts

In the introduction of this report, we already mentioned that the organization of out-of-hours care in the Netherlands has substantially changed during the last years. A promising solution to tackle the bottleneck of the high number of self-referrals at the ED is to integrate an ED with a GP post. Fry (2009) performed a systematic review on the barriers and facilitators on the success and sustainability of after-hours care in Australia. By considering these factors in the organization of after-hours care, it could lead to a decrease in the demand of acute services, increased health outcomes, model sustainability, and a greater utility. These barriers and facilitators are also suitable in the Netherlands, and can be taken into account when considering changes in the organization of out-of-hours care.

Between the years 2002 and 2005, fourteen Dutch papers have been published with policy advices on the organization of emergency care. The conclusion of these papers all tend towards more cooperation and integration between GP posts and EDs. These conclusions are based on the belief that extensive cooperation can lead to more effective, efficient and coordinated emergency care. Extensive collaboration between GP posts and EDs can offer the following solutions to the existing bottlenecks (Vermue, Giesen & Huibers, 2007):

- Clarity for the patient: the patient does not have to choose anymore between different health care providers, they are always at the right place.
- Deflection of self-referrals from EDs to GP posts: the most complex and urgent patients are treated at the ED, and the less urgent patients at the GP post. Because less urgent patients are not treated at the ED anymore, the waiting times will decrease at the ED. In addition, unnecessarily costly care and medicalization of less urgent care will decrease.
- Decrease of inefficient deployment: through integration there will no longer be two teams of health care providers working in parallel.
- Increase in job satisfaction: the health care professionals working at the GP posts or the EDs can do the job for which they are trained.
- Decrease in the cultural differences between the two organizations, as a result of more cooperation.
- Decrease in discontinuity of care, as a result of the use of an electronic medical record. In addition, through better coordination of medical policies between the GP en the specialist, less errors will occur.

There are several organizational models of cooperation between GP posts and EDs. Vermue, Giesen & Huibers (2007) differentiate between four models from the Netherlands. In model 1, cooperation between the two organizations is limited to the referrals from the GP post to the ED. In model 2, all self-referrals that come to the ED are triaged and are referred to the GP post, unless the patient clearly requires the specialized care of the ED. In model 3, the GP post functions as a gatekeeper for the ED. All self-referrals that come to the GP post and the ED have access to the GP post. Specialized care at the ED is only accessible after a referral from the GP post. In the final model, model 4, there is one common triage point at which all self-referrals are triaged. After triage, the patients will either be referred to the GP or to the ED, depending on the severity of the symptoms of the patient.

During the last years, some integrated emergency posts (IEPs) have been established and in other regions they are preparing to establish such a service. A number of researchers have investigated the effects of an integrated emergency post. Kool, Homberg & Kamphuis (2008) investigated whether the expectations of an ED are actually realized. They concluded that there was indeed a shift from secondary to primary care and an increased patient satisfaction with telephone contact. However, there was no significant difference in patient satisfaction between the patients who visited an IEP and patients who visited a NIP. In addition, job satisfaction of employees working at an IEP was lower than the job satisfaction of employees working at a NIP. According to the authors, this is most likely due to the dramatic changes in the work processes.

In the framework of the ZonMw project about optimal logistics and patient preferences in the acute care chain, Visser (2011) designed a conceptual model of the IEP in Almelo. Based on this research, Mes and Bruens (2012) presented a generalized simulation model of an IEP. Two follow-up projects emerged from this research. Van der Linde (2012) used this model and analyzed the benefits of an IEP in Almelo. He made a comparison between the non-integrated emergency post (NIP) and the IEP. He concluded that due to integration, the waiting times and the workload at the ED post decreases, while the waiting time and the workload at the GP post increases. By introducing a nurse practitioner at the GP post in the weekend, the workload and the amount of overtime is reduced to a similar level as with a NIP. Overall conclusion of this study is that the IEP is preferred, based on a higher level of patient satisfaction, equal or reduced workload at both organizations, and a reduction in organizational overlap. Borgman (2012) analyzed several scenarios in order to optimize the IEP in Almelo. Examples of these scenarios are: weekend nurse practitioner replacement with a resident, treating low urgency ED patients in GP post rooms, using a single triage system, direct bed admission requests for ED patients that are likely to be admitted, and some other.

2.5 Flexible simulation frameworks

The previous section describes a simulation model that is based on the IEP in Almelo, the Netherlands. Mes & Bruens (2012) state that this simulation model is general and can be easily adapted to other EDs as well as to other hospital departments, but this statement has not yet been verified. Zeltyn, et al. (2011) do have demonstrated the general applicability of a simulation model in health care. They developed a single well-designed simulation model of an ED that can be instrumental to solve ED staff schedules problems. They tested the flexibility of the simulation model by using it in nine Israeli hospitals. They conclude that the simulation model can be tuned to meet the needs of other EDs in Israel and around the world. Ferrin, Miller & McBroom (2007) have developed a semi-reusable product, that is used in a hospital in Arizona to quickly model and test alternative design scenarios for existing and proposed hospital EDs. Fletcher, Halsall, Huxham & Worthington (2007) describe the development and application of a generic simulation model that is used in several hospitals in the UK. Facchin, Rizzato & Romanin-Jacur (2010) developed and implemented a generalized simulation model of the ED at several EDs in different types of hospital in North-East Italy. They used the simulation model at each hospital by only changing parameters and inputs, without structural modifications.

Sinreich & Marmor (2004) describe the foundation for the development of a simulation model for analyzing ED performance. They state that a simulation model must be simplified as much as possible, and that the simulation model has to be general, flexible, intuitive, simple to use, and it has to include default values for all system parameters. By using these principles, they state that the managements' involvement and confidence in the simulation model will increase, and that the effort to develop a simulation model will decrease. For these reasons, they think that the use of simulation will increase. From the preceding section, in which we described some examples of generic simulation models, it appears that a generically built simulation model indeed can be adapted to other emergency departments without much effort. This shows the great advantage of a generic simulation model.

2.6 Our contribution

This aim of this study is to determine the effects of integrating the ED of MST with the local GP post. In determining this effect, the simulation model described by Mes and Bruens (2012) will be used. They state that the simulation model is flexible and general and can easily be adapted to other emergency department as well as to other departments within a hospital. By using it in a different setting, we will verify whether their statement is correct. If not, we will make adjustments in such a way that the model is more broadly applicable to other settings. So, the contribution of this work is twofold, 1) societal contribution, due to extension of knowledge on efficient organization of out-of-hours care, and 2) scientific contribution, due to the verification (and appropriate adjustments) of a flexible simulation framework for the analysis of IEPs.

2.7 Summary

In this chapter, we searched the literature for what was already known about simulation, simulation in health care, out-of-hours care, and simulation of out-of-hours care. We described what simulation is, what the advantages and disadvantages are of simulation, and how a sound simulation study should be performed. Furthermore, we described that simulation is already applied in a variety of fields, and that it offers great potential for health care. This could also be seen from the substantial increase in the number of publications related to simulation in health care. In addition, we have seen that simulation was also previously used in modelling patient flow and resource allocation at emergency departments. Last, we described that some authors already proved the general applicability of a simulation model, and that the use of generic simulation models shows great advantages.

3 Process and data analysis

This chapter describes the current situation at the GP post and the ED. We start with a description of the ways in which a patient can go through the non-integrated emergency post (NIP) in Enschede in Section 3.1. In Section 3.2, we describe the arrival process at the both organizations. In Section 3.3, the patient variables and the patient related dependencies are described. Section 3.4 describes the resources that are relevant for the processes at the GP post and at the ED, after which the sub processes at the GP post and the ED are described in Section 3.5. After the analysis of the current situation, a description follows of the changes that need to be made in the transition towards an integrated emergency post (IEP) in Section 3.6.

3.1 Paths through a NIP

In a non-integrated emergency post (NIP), the ED and the GP post work separately. Cooperation between the two organizations is limited to the referrals from the GP post to the ED. A patient can access the GP post in two ways: by calling, or by going to the GP post as a self-referral. When a patient calls the GP post, the GP assistant performs a telephonic triage to determine the urgency of the patient. Based on this urgency, the GP assistant determines the appropriate follow-up for the patient; there are four options:

- When the symptoms of the patient are not urgent enough to schedule an appointment, the GP assistant gives the patient telephonic advice and the patient leaves the system.
- If the complaints of the patient are urgent, he or she receives an appointment time for consultation at the GP post. The waiting time for this consultation is dependent on the urgency.
- If the complaints of the patient are severe, the GP assistant sends the patient to the ED. This can be done in two ways: 1) the patient goes to the ED on his own or 2) the GP assistant sends an ambulance to the patient to transfer the patient to the ED.
- Sometimes, it is impossible or medically not advisable for the patient to come to the GP post. However, if the patient does need acute primary care, the GP visits the patient at home to treat the patient there. If this treatment is sufficient, the patient stays home and leaves the system of the GP post. In some cases, the treatment is insufficient and the patient is send to the ED by ambulance.

In some cases, the patient directly goes to the GP post without calling. When the patient arrives at the GP post, the GP assistant performs a physical triage. Depending on the urgency of the symptoms, the patient gets one of the following follow-up options:

- If the complaints are not urgent, the patient gets medical advice and goes home. The patient leaves the system.
- If the patient needs acute medical care, he or she gets an appointment time for consultation. The waiting time for this consultation is dependent on the urgency.
- In some cases the urgency of the patient is very high and the patient directly needs specialized care. In those situations the patient is sent to the ED.

If a patient receives an appointment time for consultation, it is intended that the patient is treated by a GP at the given time (or earlier, when it is quiet). The GP determines, based on the consultation, the correct follow-up for the patient. Again, there are several options:

- The treatment and/or medical advice of the GP is sufficient, the patient goes home and leaves the system.
- The GP assesses the symptoms as urgent and decides that the patient needs specialized care. The GP refers the patient to the ED and the patient leaves the system of the GP post.
- In case the GP expects a fracture, an X-ray is made at the radiology department. If it turns out that there is indeed a fracture, the patient goes to the ED for further treatment. When it does not concern a fracture, the patient goes home and leaves the system.

We can also distinguish several options to enter and to leave the ED. A patient can access the ED in three ways:

- The first way to enter the ED is as external referral. An external referred patient is a patient from which is known in advance that he or she is coming to the ED. The patient can be referred or by their GP, by an internal or by external medical specialist. Another option is that the patient comes to the ED by ambulance or helicopter and is pre notified. Also the police can refer a patient to the ED. And last, it is possible that the patient has telephonic contact with the ED prior to the visit.
- The second option to enter the ED is as GP post referral. This is only possible outside office hours. A GP post referral can directly come from the GP post or may end up at the ED after X-ray.
- The third option to enter the ED is as a self-referral. These patients skip the GP (post) and directly go the ED. Sometimes this is a fair choice, but this does not apply to all self-referrals.

All the patients coming to the ED follow broadly the same path. The first step is a physical triage of the patient in which the urgency is determined on the basis of the complaints. After triage, the patient has to wait for further examination. This waiting time is dependent on the urgency of the patient and the resource availability at the ED. After triage, further diagnostic test are performed in order to determine the diagnosis. When the diagnosis is known, the patient receives the appropriate treatment.

The patient can leave the ED in three ways:

- The patient is going home, with or without a follow-up consultation.
- The patient is admitted to the acute admission ward or another hospital ward for further treatment.
- The patient is transferred to another hospital.

Figure 4 gives an overview of the paths a patient may follow. A description of all the possible paths at the GP post and the ED is given in Table 7. As can be seen from this table, we distinguish A, B, C, and X-paths. Path A1 represents the path through with all ED self-referrals go, path A2-A8 represents the arrival options at the GP post. The B-paths represents the various process paths a patient can go through at the GP post. The C-paths represents the departure options after discharge from the ED. The X-path represents the arrival path at the ED. Remarkable is that this is only one arrival path in contrast to the three arrival options mentioned in the section above. This is because the ED self-referrals already come through path A1, and the GP post referrals come through path A5, A7, B3, or B4.

Non-integrated emergency post

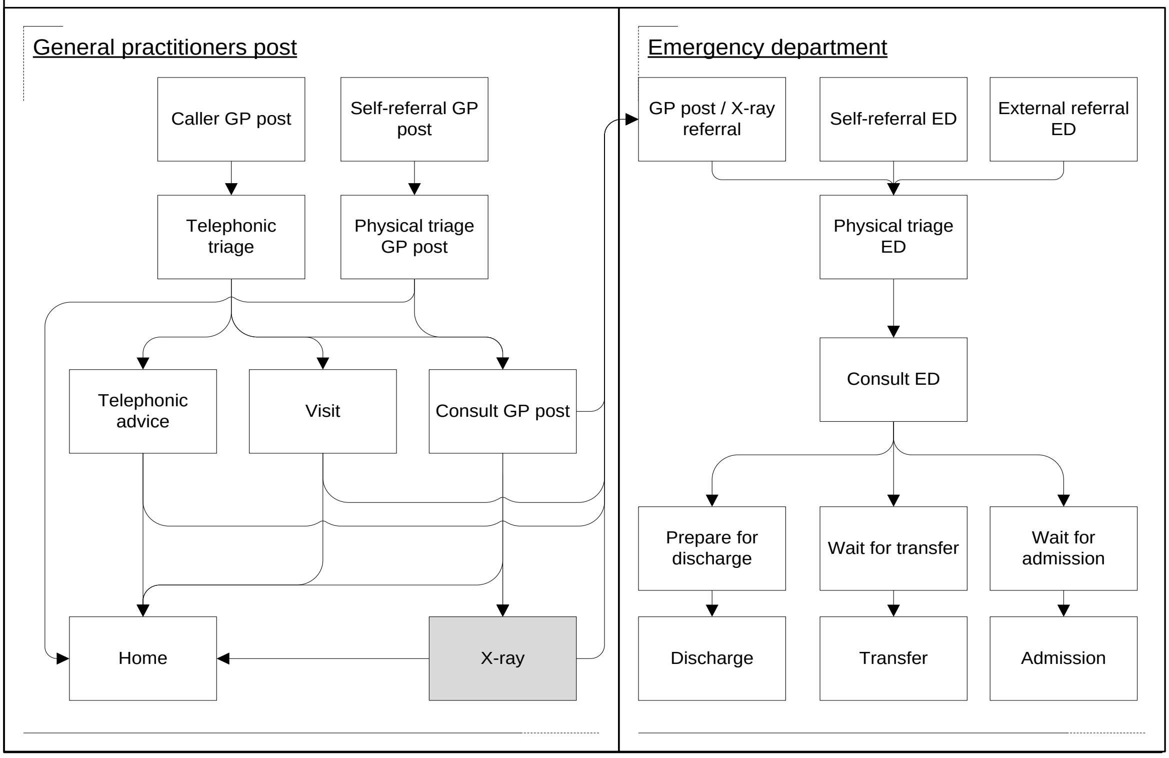


Figure 4
Flowchart non-integrated emergency post

Table 7
Paths through a non-integrated emergency post

Group	Path
A1	Self-referral ED –ED
A2	Self-referral GP post – physical triage GP post – home
A3	Self-referral GP post – physical triage GP post – consult GP post
A4	Caller GP – telephonic triage GP post – telephonic advice – home
A5	Caller GP – telephonic triage GP post – (telephonic advice) – ED
A6	Caller GP – telephonic triage GP post – visit – home
A7	Caller GP – telephonic triage GP post – visit – ED
A8	Caller GP – telephonic triage GP post – consult GP post

Group	Path
X	External – ED

Group	Path
B1	Consult GP post – home
B2	Consult GP post – X-ray – home
B3	Consult GP post – X-ray – ED
B4	Consult GP post – ED

Group	Path
C1	ED – triage – consult ED – home
C2	ED – triage – consult ED – transfer
C3	ED – triage – consult ED – admission

3.2 Arrival process

Employees from both the GP post and the ED indicate that certain hours are busier than others. For example, GP post employees indicate that it is busier early in the evening than during the night. ED employees designate the hours in the late afternoon as busy hours. Furthermore, it appears that certain days are busier than other days. Employees from both organizations state Monday and Friday as busy days, and Tuesday and Wednesday as relative quiet days. Following these statements, we analyze historical data in order to identify such patterns. In addition, we determine the underlying statistical distribution of the arrivals by which we can correctly model the arrivals.

Inspired by Visser (2011), we look at three factors when analyzing the arrivals at the GP post and the ED. These factors are defined as follows:

Hour factor The hour factor is the average number of arrivals per hour. By determining the hour factor for each hour of the day, one can identify an arrival pattern. One the basis of this arrival pattern one can distinguish the busy hours from the quiet hours on a day.

Day factor The day factor indicates whether a particular day is busier than any other day in the week. The day factor refers to the total number of arrivals at a particular day. A day factor is calculated by dividing the number of arrivals on day *d* by the average number of day arrivals in week *w*.

Week factor The week factor refers to the total number of arrivals in a certain week. On the basis of this week factor a possible seasonal effect can be identified. A week factor is calculated by the number of arrivals in week *w* of the year *y* divided by the average number of arrivals per week in year *y*.

For both the day factor and the week factor, it holds that a factor of one indicates an average day or week in terms of the number of arrivals, a factor of smaller than one indicates a quieter day or week compared to the average, and a factor of greater than one indicates a busier day or week compared to the average.

3.2.1 Assumptions

We assume that the arrival of patients at the ED and the GP post follows a Poisson distribution. This means that the number of arrivals in a time interval of length *s* is a random variable with parameter λ. The Poisson distribution is most commonly used to model the arrival process of customers to a queuing system. A stochastic process is said to be Poisson if (Law, 2007):

- Customers arrive one at a time.
- The number of arrivals in a time interval is independent of the number of arrivals in an earlier time interval.
- The number of arrivals is independent from the time of the day.

The first two properties also apply to arrivals at the ED and the GP post. The last property is violated by many real-life arrival processes, as well as the arrival processes of our interest. However, when one takes a relatively short time interval (1- or 2-hour), the arrival rate is reasonably constant over this interval and the Poisson process is a good model for the process during this interval. This is the reason why we set the length of the time interval *t* at 1-hour. The number of arrivals in this time interval is a random variable with parameter λ. The average number of arrivals differ per hour, per day, and per week. So, the number of arrivals in *s* can be expressed by $\lambda_{h,d,w}$. This parameter is given by the following formula:

$\lambda_{h,d,w} = \alpha_h * \beta_d * \gamma_w$

$\lambda_{h,d,w}$ The number of arrivals at hour *h,* at day *d,* in week *w*
α_h Average number of arrivals at hour *h;* h ∈ 1, .., 24
β_d Day factor for day *d*; d ∈ 1, .., 7
γ_w Week factor for week *w*; w ∈ 1, .., 52

According to professionals from the GP post and the ED, the arrival pattern is not identical for each day of the week. Therefore, we assume that the hour factor is dependent on the day of the week. As a consequence of this assumption, α_h is replaced by $\alpha_{h,d}$, in which d ∈ 1, .., 7.

Now, we can come up with a formula which allows us to model the arrivals of the GP post and the ED. Because the GP post and the ED are two separate organizations, we determine the values of the above variables for the two organizations separately. Therefore, we draw two formulas. The meaning of the variables are equal to the description above. The variables with a G in superscript are applicable to the GP post, the variables with an E in superscript are applicable to the ED.

$\lambda^G_{h,d,w} = \alpha^G_{h,d} * \beta^G_d * \gamma^G_w$
$\lambda^E_{h,d,w} = \alpha^E_{h,d} * \beta^E_d * \gamma^E_w$

3.2.2 Arrivals GP post

In this section we perform a historical data analysis in order to determine the values of $\alpha^G_{h,d}$, β^G_d, and γ^G_w. For the analysis of the arrivals of the GP post, we used data from all full weeks of 2012 and 2013. National holidays are excluded from the analysis, because we want to base the analysis on regular days.

First, we determine the values of the hour factors $\alpha^G_{h,d}$. Based on visual judgement, we assume that all weekdays have the same arrival pattern, i.e. they have the same busy and quiet days (see Figure 5). In the weekends, the GP post is also opened between 08:00 am and 17:00 pm. Therefore we use a different arrival pattern for Saturday and Sunday. Besides, we split up the analysis of Saturday and Sunday, because we see another arrival pattern on those days (see Figure 5). We separately calculate the hour factors for the weekdays, for Saturday, and for Sunday. The results are given in Table 43 in Appendix B.

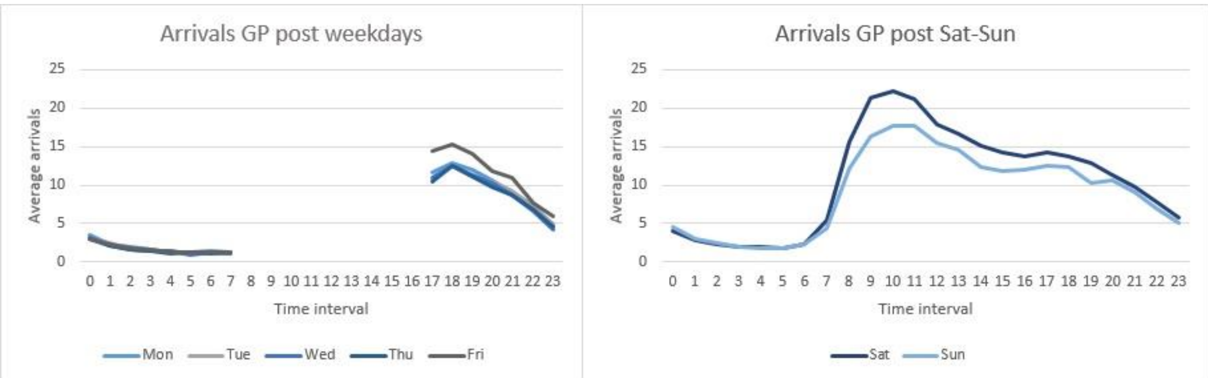


Figure 5
Average arrivals GP post per day

The next step is to determine the day factors for the GP post. The days are compared by making use of two sample student's *t*-tests. The results of the tests are given in Table 8. We see that Monday and Friday are significantly different from every other day, when we use a significance level α of 0.05. Monday and Friday are also significantly different from each other. From these observations we assume that Tuesday, Wednesday, and Thursday are not significantly different regarding to the number of arrivals. Monday and Friday have different underlying arrival distributions. Because we use a separate hour factor for Saturday and for Sunday, we base the day factor of these days on the average arrivals on that specific day.

Table 8

P-values two sample t-test weekdays GP post

	Tuesday	**Wednesday**	**Thursday**	**Friday**
Monday	0.024*	0.008*	0.003*	0.000*
Tuesday	-	0.681	0.380	0.000*
Wednesday	-	-	0.620	0.000*
Thursday	-	-	-	0.000*

* Significant difference with α = 0.05

The underlying distribution of the day factors are determined by making use of the software package Minitab version 16. The day factors are tested to the Normal, Lognormal, Exponential, Weibull, and the Gamma distribution, by making use of the Anderson-Darling test. The outcomes of this test are given in Table 44, Appendix B. The chosen distributions for the days are given in Table 9, with the corresponding histogram in Figure 36, Appendix B.

Table 9

Underlying distributions day factors GP post

Day of the week	**Distribution**	**P1**	**P2**
Monday	Normal	1.0022	0.1300
Tue-Thu	Normal	0.9500	0.1473
Friday	Lognormal	1.1440	0.1912
Saturday	Lognormal	1.0000	0.1124
Sunday	Lognormal	1.0000	0.1234

Normal: P1 = mean, P2 = standard deviation; Lognormal: P1 = mean, P2 = standard deviation

Next, we look at the week factors for the GP post. Figure 6 shows the average week factors for the GP post arrivals. One can see that through the year no seasonal effect can be distinguished. Remarkable is the increase in the number of arrivals in the last weeks of the year, but also the increase in standard deviations of those weeks. One should interpret these factors with care, because they are based on only two years of data. Due to this, the average can be sensitive to outliers. The standard deviations for the other week factors are relatively small, meaning that the number of arrivals in those weeks do not fluctuate greatly.

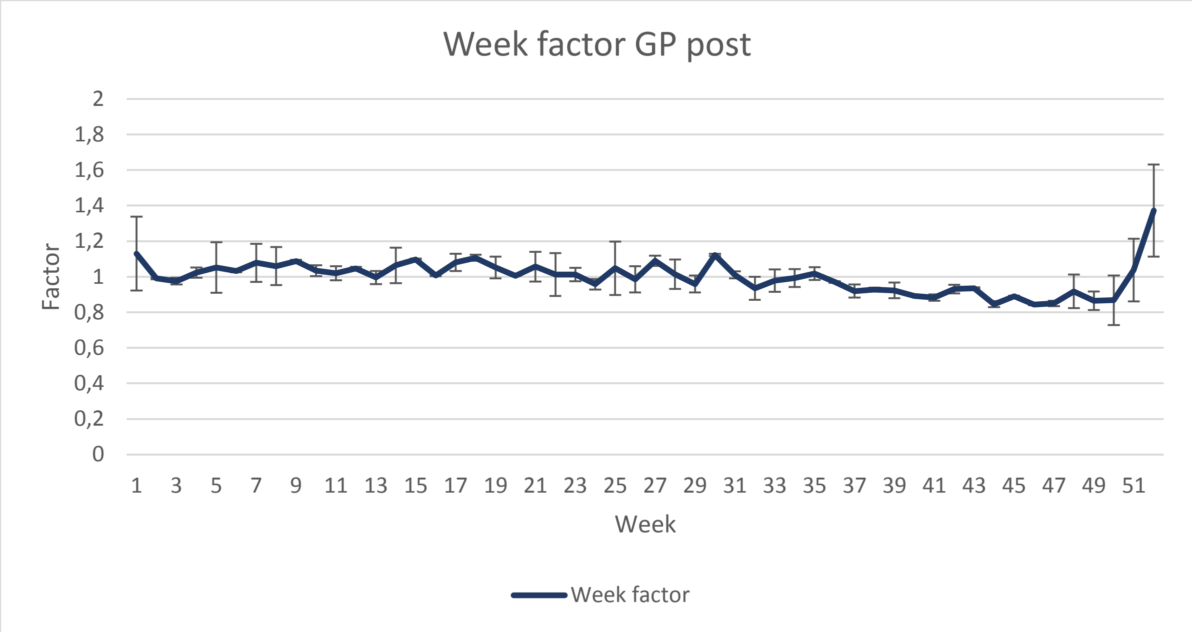


Figure 6
Average week factors GP post (n = 104)

The best fitting underlying distribution for the week factor of the GP post is also determined by making use of the Anderson-Darling test in Minitab. The outcomes of this test are given in Table 45 in Appendix B. The best fitting distribution for the week factors at the GP post is a lognormal distribution with a P-value of 0.111. The corresponding parameters are given in Table 10, the corresponding histogram is given in Figure 37, Appendix B.

Table 10
Distribution week factors GP post

Week	Distribution	P1	P2
1-52	Lognormal	1.0000	0.1118

Lognormal: P1 = mean, P2 = standard deviation

3.2.3 Arrivals emergency department

In this section, we continue the historical data analysis in order to determine the values of $\alpha^E_{h,d}$, β^E_d, and γ^E_w. We use the same methodology as for the GP post arrivals. However, this analysis uses a smaller data set. Before September 2013, all patients from internal medicine were treated by their own private acute care unit. However, from September 2013, these patients were treated at the ED. Due to this change, the number of arrivals at the ED changed. Because these patients will also be treated at the ED in the future, we base the analysis of the arrivals at the ED on data from September 2013. Again, national holidays are excluded from the analysis.

First, we analyze the arrival pattern for all days of the week. Based on visual judgement of Figure 7, we assume that the arrival patterns for the weekdays are the same. Saturday and Sunday have the same arrival pattern, but this arrival pattern differs from the arrival pattern of the weekdays. So, we use one hour factor for the weekdays, and one for the weekend. The hour factors for the weekdays and for the weekend are given in Table 46 in Appendix B.

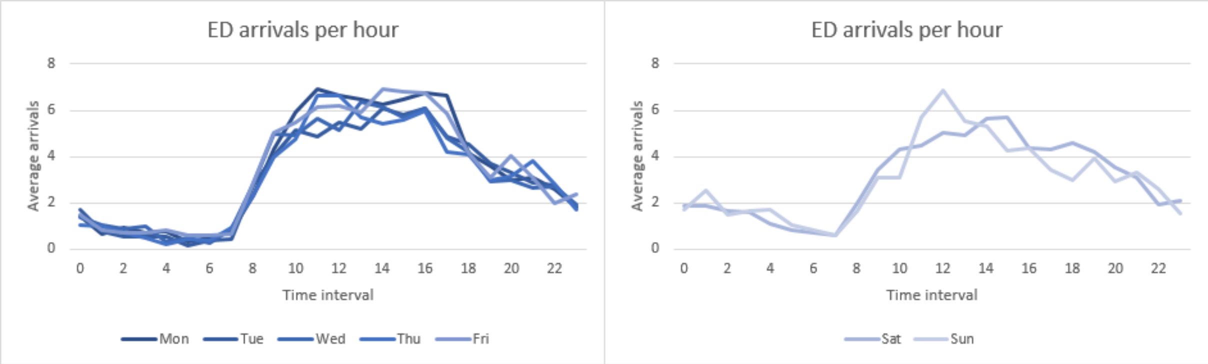


Figure 7
ED arrivals per hour

Next, we determine the day factors for the ED. By making use of a student *t*-test in the comparison of the weekdays, we see that Monday is significantly different from Tuesday and Thursday, but not from Friday (see Table 11). There is no significant difference between Tuesday and Thursday. Wednesday does not significantly differ from any other weekday. Because the p-values for the difference between Tue-Wed and Wed-Thu are higher than the p-values for the difference between Mon-Wed and Wed-Fri, we classify Wednesday to Tuesday and Thursday. If we compare Saturday and Sunday, it appears that they are not significantly different (P-value = 0.577). Based on this, we assume that the following days are not different with regard to the number of arrivals: Monday and Friday; Tuesday, Wednesday, and Thursday; Saturday and Sunday.

Table 11
P-value t-test weekdays ED

	Tuesday	**Wednesday**	**Thursday**	**Friday**
Monday	0.011*	0.071	0.0250*	0.945
Tuesday	-	0.568	0.851	0.006*
Wednesday	-	-	0.711	0.054
Thursday	-	-	-	0.017*

* Significant difference with α = 0.05

Again, the underlying arrival distributions of the day factors are determined by making use of the Anderson-Darling test in Minitab. The outcomes of this test are given in Table 47, Appendix B. The chosen distributions for the days are given in Table 12. The corresponding histograms are given in Figure 38, Appendix B.

Table 12
Distribution day factors ED

Day of the week	**Distribution**	**P1**	**P2**
Mon & Fri	Lognormal	1.0600	0.1246
Tue-Thu	Normal	0.9584	0.1172
Sat & Sun	Normal	1.0000	0.1238

Normal: P1 = mean, P2 = standard deviation; Lognormal: P1 = mean, P2 = standard deviation

Finally, we analyze the week factors to determine whether we can distinguish seasonal effects in the number of arrivals at the ED. Because we only analyzed seventeen weeks for the ED, it is impossible to analyze week factors for every week of the year. Besides, because those seventeen weeks are data from only one year, it will be sensitive to outliers. A solution for this is to divide the arrivals in the weeks in which the patients from internal medicine entered the ED by the average number of arrivals of those seventeen weeks. The other 35 weeks in 2013 are divided by the average number of arrivals in the first 35 weeks of 2013. This allows us to make use of the data of all weeks in 2012 and 2013. Figure 8 shows the result of this analysis. The week factors seems to be stable over the year, and we cannot distinguish seasonal effects.

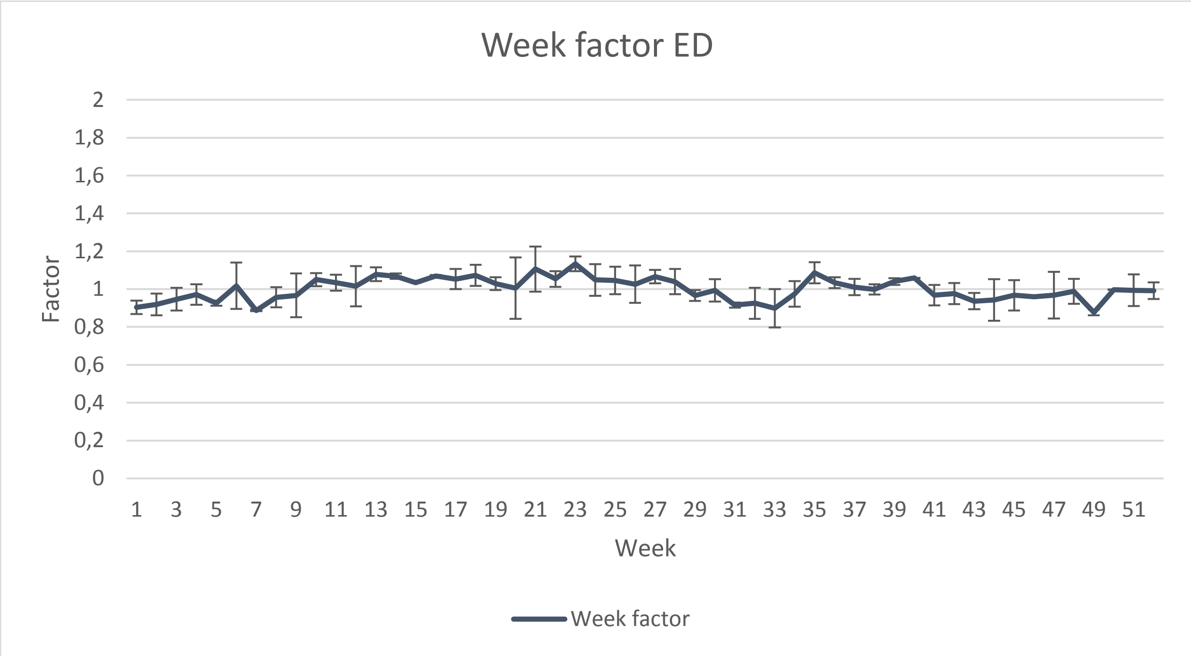


Figure 8
Week factors ED (n = 104)

The best fitting underlying distribution for the week factor of the ED is also determined by making use of the Anderson-Darling test in Minitab. The outcomes of this test are given in Table 48, Appendix B. The best fitting distribution for the week factors of the ED is a Weibull distribution with a P-value of 0.202. The corresponding parameters are given in Table 13, the corresponding histogram is given in Figure 39, Appendix B.

Table 13
Distribution week factors ED

Week	**Distribution**	**P1**	**P2**
1-52	Weibull	14.57295	1.03463

Weibull: P1 = shape, P2 = scale

3.3 Patient groups

A distinction can be made between patients on the basis of several variables. One of these variables is the urgency of a patient, which is determined according to a certain triage system. The ED of MST uses the Manchester Triage System. This system works with five urgency levels; red (immediate), orange, yellow, green, and blue (non-urgent). The GP post works with the Netherlands Triage System. This system also works with five urgency levels; U1 (life-threatening) till U5 (non-urgent). The maximum allowable waiting time of a patient is dependent on the determined urgency of that patient. The maximum waiting times are given in Table 14.

Table 14

Urgency vs. maximum waiting time

GP post urgency	Maximum waiting time	ED urgency	Maximum waiting time
U1	15 minutes	Red	0 minutes
U2	60 minutes	Orange	10 minutes
U3	180 minutes	Yellow	60 minutes
U4	No max. waiting time	Green	120 minutes
U5	No max. waiting time	Blue	240 minutes

In addition, the patients arriving at the ED can be categorized into specific treatment groups. These treatment groups distinguish themselves by the type and the number of diagnostic tests a patient must undergo. Besides, the treatment groups have different treatment times. For example, the probability that cardiology patients receive an ECG is high, but this does not apply for patients with a suspected bone fracture; their chance on a X-ray is higher. This has implications for the process a patient goes through at the ED and for the treatment time. We distinguish twelve treatment groups, which are given in Table 15. As basis, we used the ten treatment groups proposed by Visser (2011). Based on expert opinion, these ten groups are changed and expanded to twelve. A similar distinction between distinctive treatment groups is not made for patients arriving at the GP post, because the treatment of these patients does not differ with regard to diagnostic tests and treatment times.

Table 15

Overview treatment groups

Nr.	Description
1	Surgical/orthopedic – Trauma – Fracture
2	Surgical/orthopedic – Trauma – Wound
3	Surgical/orthopedic – Trauma – Other
4	Surgical/orthopedic – Abdomen
5	Surgical/orthopedic – Rest
6	Cutting specialties – Other
7	Neurological – Stroke
8	Pulmonary medicine
9	Internal medicine
10	Contemplative specialties – Other
11	Trauma
12	Cardiology

3.3.1 Patient group vs. time

In Section 3.2, a description is given of the number of arrivals per time interval. The underlying assumption was that the number of arrivals at the GP post and the ED is dependent on the time. In this section, we analyze whether the patients variables urgency and treatment group are also time dependent.

Urgency

According to experts from both organization, the urgency distribution of the arrivals may differ per day and per hour of the day. Therefore, we analyze the urgency distribution per day and per arrival hour. We calculate the probability of an urgency level *u* during time interval *t*. The time interval in this analysis has a length of one day or one hour. The probability on urgency level *u* is calculated by the number of patients with urgency *u* in time interval *t* divided by the total number of arrivals in time interval *t*. Because the GP post and the ED have different triage systems, we split up the analysis for both organizations. The results are given in Figure 9. In Figure 9a and Figure 9c, we see that the urgency distribution does not fluctuate per day for both the GP post urgency distribution as for the ED urgency distribution. However, in Figure 9b and Figure 9d, we see that patients arriving during the night generally have a higher urgency than the patients arriving during the day (for both organizations). The exact probability on urgency level *u* in time interval *t* for both the GP post and the ED is given in Appendix C.

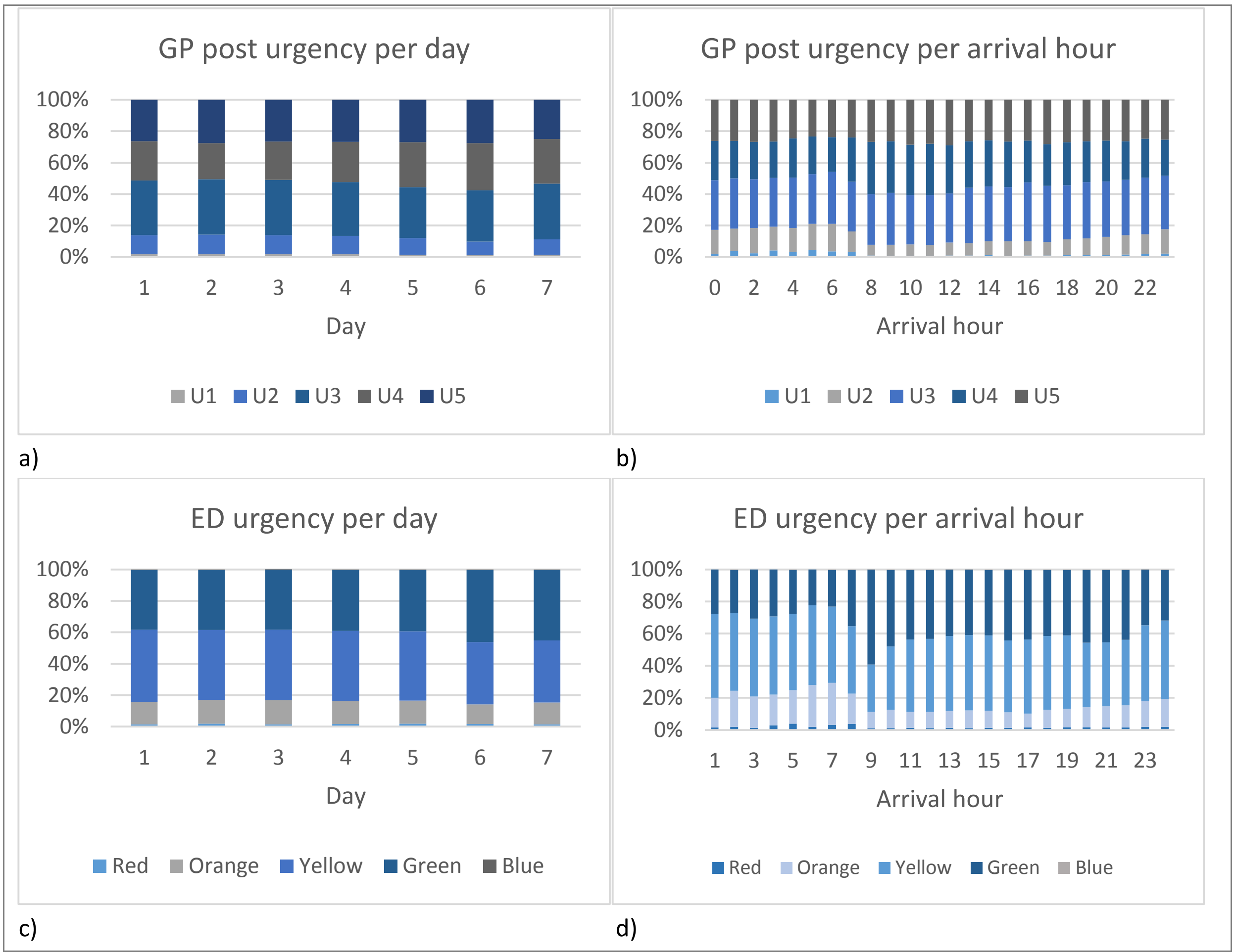


Figure 9
Patient urgency per time interval

Patients can arrive at the ED in three different ways: the patient is referred by an external specialist or organization, the patient is referred by the GP post, or the patient comes to the ED on its own initiative (see Figure 4). After analysis, it appears that the urgency distribution of the patients varies per arrival type, Figure 10 supports this. Due to this, we calculate the probability on urgency level *u* in time interval *t* for each arrival type separately. The results are given in Appendix D.

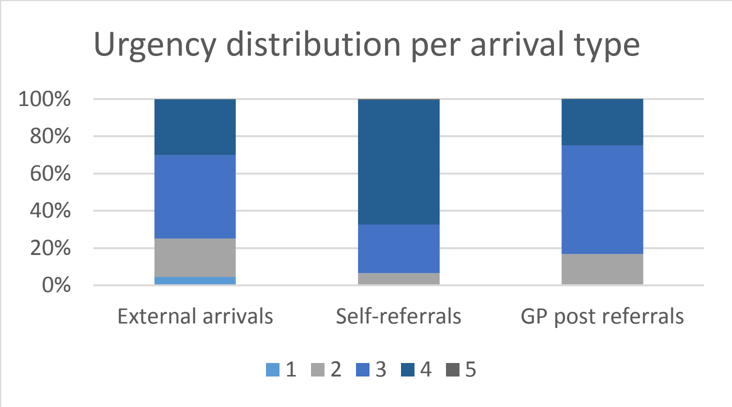


Figure 10
Urgency distribution per arrival type

Treatment group

The other variable to analyze is treatment group. According to experts from the ED, there is a different case mix during the night than during the day. We want to verify this statement by making use of the same method of analysis as used in the previous section. However, due to missing data, we cannot assign all the patients to a treatment group. The treatment group of the patient is derived from the registered entrance complaint (EC), which is determined during triage. However, it appears that 34.7% of the cases is not correctly registered according to the Manchester Triage System, due to which we cannot derive the EC of those patients. Because this is a large part of the data set, it is important to analyze whether the group patients without an EC is equivalent to the group with an EC. When the groups are not equal, we have to find a way in which we can correct for the differences between the two groups. The following section describes how we deal with these missing data.

Missing data

We compare the group with an EC with the group without an EC by using the Chi-Square test in SPSS. We compare the two groups based on gender, age, urgency, arrival hour, arrival day, and arrival year. It appears that the group without EC differs from the group with EC with regard to all the characteristics, see Appendix E for the results. Therefore, we have to correct for the differences between the two groups. For this purpose, we took a random sample of 800 from the 18,240 patients without an EC. Again, we use the chi-square test for the comparison between two groups; the sample and the control group (the other 17,420 patients without EC). We conclude that the random sample of 800 patients does not differ from the control group based on the six characteristics mentioned earlier in this section. Therefore, we assume that the random sample is an accurate representation of the group without EC and that we can use it in the determination of the distribution of certain variables in the group without EC. Appendix F gives an overview of the outcomes of the Chi-Square tests.

Thereafter, two reviewers have independently subdivided the 800 patients in the sample into one of the twelve treatment groups. The results of the two reviewers are compared by making use of the Cohen's kappa coefficient. Cohen's kappa coefficient is a statistical measure of inter-rater agreement for qualitative, categorical items, correcting for expected chance agreement (Viera & Garrett, 2005). The coefficient is calculated by the following formula:

$$\kappa = \frac{P(A) - P(E)}{1 - P(E)}$$

In this formula, P(A) is the proportion of times that the coders agree, and P(E) is the proportion of times that they would expect to agree by chance, calculated along the lines of the intuitive argument presented above. The coefficient of the inter-rater agreement in the analysis of the sample is 0.77. According to Viera & Garrett (2005), this value means 'substantial agreement'. The reviewers re-examined the cases in which the classification did not correspond, and have drawn a conclusion about these cases based on consensus.

Treatment group versus time

Now that we know the distributions of the treatment groups in the group with EC and the group without EC, we can analyze the percentage of patients within treatment group *s* in time interval *t*. This percentage is calculated by dividing the amount of patients with treatment group *s* in time interval *t* by the total number of patients in time interval *t*. Due to the relative small sample of 800 patients to determine the distribution of treatment group in the group without EC, some time intervals may be underrepresented. To avoid this problem, we use a 4-hour time interval in the analysis of treatment group per arrival hour. The time intervals are: 12:00 am – 03:59 am; 04:00 am – 07:59 am; 08:00 am – 11.59 am; 12:00 pm – 03:59 pm; 04:00 pm – 07:59 pm; 08:00 pm – 11.59 pm. Figure 11 shows the results of the analysis. We see that the treatment group arrivals do not fluctuate per day. In Figure 11b, we see a small difference between the treatment group arrivals per arrival hour. The exact probabilities of patients within treatment group *s* in time interval *t* are given in Appendix G.

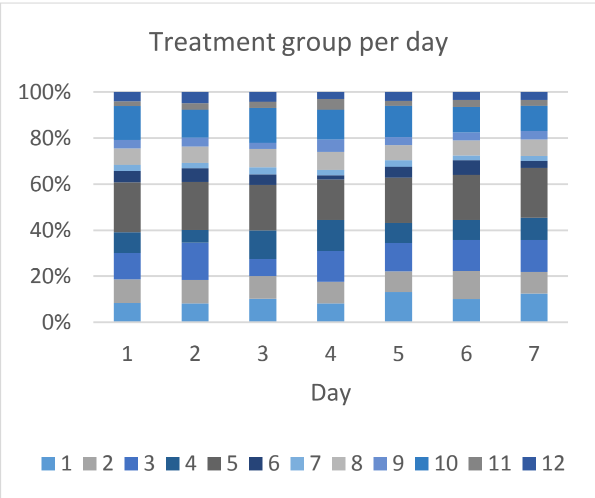


Figure 11a
Treatment group per day

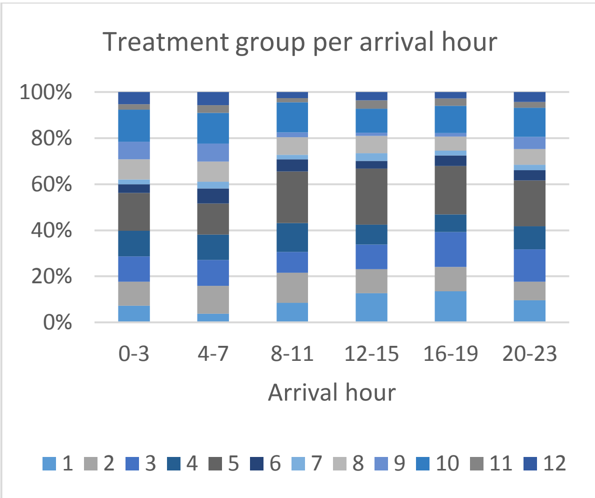


Figure 11b
Treatment group per arrival hour

Inspired by the fact that the urgency distribution per arrival type differs, we also conduct an analysis on the treatment group distribution per arrival type, Figure 12 shows the results. In this figure, we see that the treatment group distribution per arrival type also differs. Due to this, we calculate the probability on treatment group *s* in time interval *t* for each arrival type separately. The treatment group distribution per arrival type is given in Appendix H.

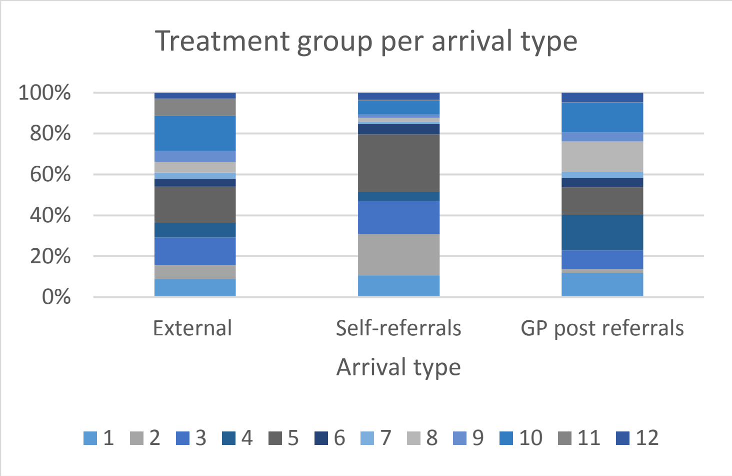


Figure 12
Treatment group per arrival type

3.3.2 Patient group vs. path

In the previous section, we described that urgency and treatment group are time dependent variables. In addition, we assume that the A-path a patient goes through at the GP post depends on the urgency of the patient. For example, the probability that an U1-patient enters the GP post by himself and is sent home with advice from the GP assistant is low (and probably zero). However, this probability for an U5-patient is much higher. Figure 13 supports this assumption. The exact probability is given in Table 59, Appendix I.

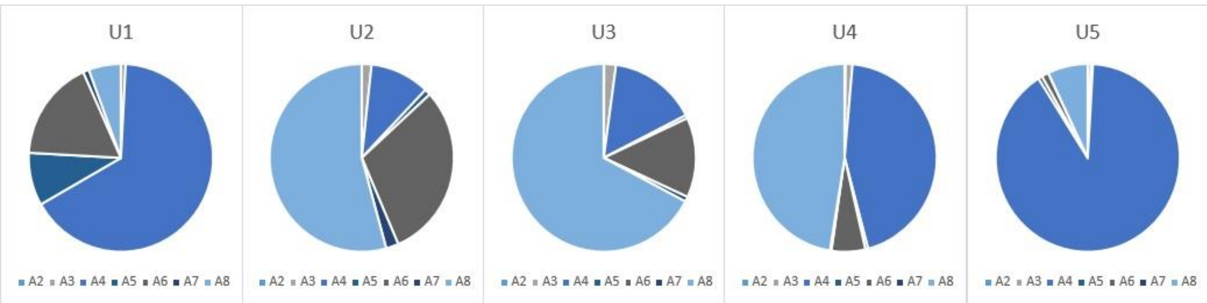


Figure 13
Urgency GP post vs. path A

Remarkable in Figure 13 is the large number of U1-patients that follow path A4, caller GP post → telephonic triage GP post → telephonic advice → home. This is due to the way in which the data of the GP post is converted in order to make it usable for this research. For example, if an U1-patient is visited by a home care or maternity care organization, the patient is no longer under the care of the GP post and the patient is not referred to the ED. Therefore, the patient no longer affects the processes at the GP post and the ED, and is registered as going "home". We also see this if we split up the U1-patients that follow path A4: 4.6% actually goes home, 92.5% is visited by an organization other than the GP post, and 2.8% is send to the hospital (other department than the ED; see Figure 14). Such a distortion may also occur in the diagrams of U2 till U5.

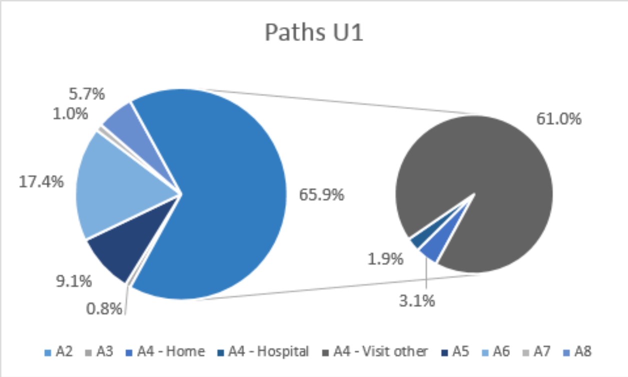


Figure 14
U1 vs. A-paths

The probability that a patient follows a certain path after consultation (B-paths) does not only depend on urgency, but also on the medical complaint of the patient. Because the patients that enter the GP post are not assigned to a particular treatment group, we base the probability of going through a certain B-path on historical fractions. The results are given in Table 56, Appendix I.

We assume that the probability of passing through a C-path is dependent on the urgency of the patient and the treatment group of the patient. The C-path in which patients are transferred to another hospital rarely occurs in Enschede (0.64% of all cases). According to experts from the ED, this group has little influence on the processes at the ED. Therefore, we do not treat these patients as a separate group, but as *being admitted to a hospital ward*, path C3. Figure 15 shows the relationship between urgency and path C, Figure 16 shows the relationship between treatment group and path C. The exact probabilities are given in Table 57 and Table 58 in Appendix I.

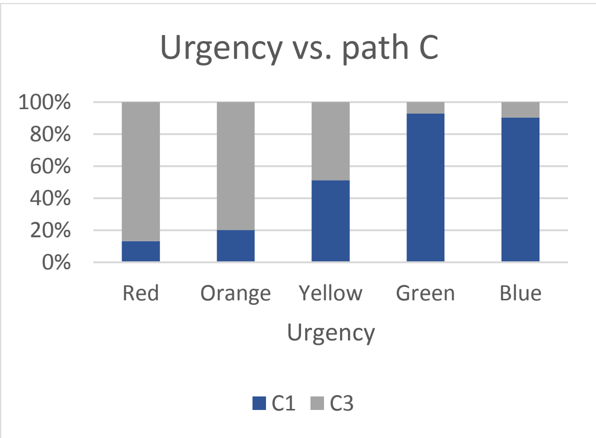


Figure 15
ED urgency vs. path C

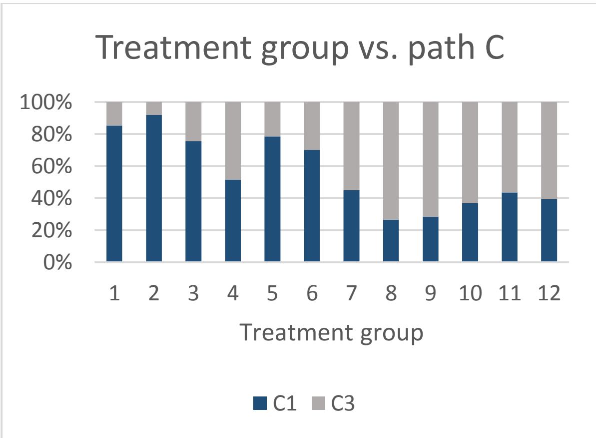


Figure 16
Patient group vs. path C

3.3.3 Treatment group vs. urgency

In the previous section, we analyzed the relationship between the patient variables and time, and between the patient variables and path. In addition, it is also possible that there is a relationship between the patient variables *urgency* and *treatment group*. Therefore, we analyze the percentage of patients with urgency level *u* in treatment group *s*. This percentage is calculated by dividing the amount of patients with urgency level *u* in treatment group *s* by the total number of patients in treatment group *s*. Figure 17 shows the results of the analysis. We see that the urgency distribution in the various treatment groups are different. For example, treatment group 11 has more urgent patients than treatment 1. The exact probabilities are given in Table 58 in Appendix G.

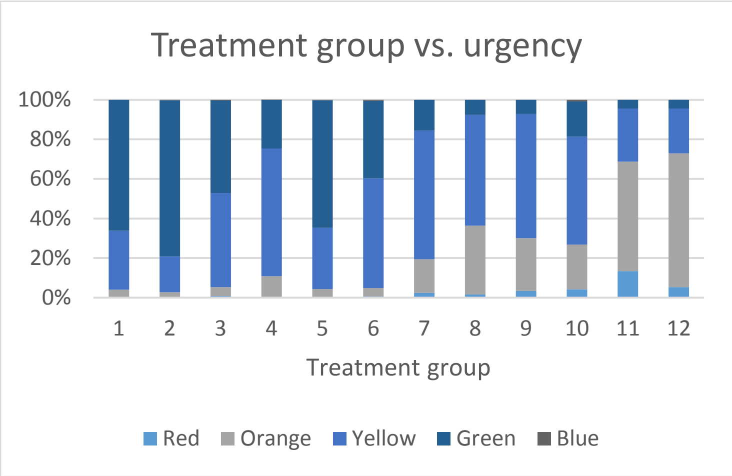


Figure 17
Urgency vs. treatment group

3.4 Resources

At the GP post and the ED many resources are used. A distinction can be made between rooms and personnel. This section provides an overview of the amount of resources per treatment group and the specific characteristics of those resources.

In the construction of the new hospital, the GP post and the ED are initially drawn as separate departments. However, in the design a possible integration is taken into account, by positioning the two departments next to each other. For both organizations, different types of rooms are designed, some of which have distinctive characteristics. An example of a room with a distinctive characteristic is the fast-track room of the ED (in the IEP). This room can accommodate three patients, with low urgent complaints. Table 16 gives an overview of all types of rooms, their quantity, and their characteristics.

Table 16
Rooms

Organization	Room type	Amount	Characteristics
GP post	Examination room	4	
	Treatment room	2	
	Triage room	1	
Emergency department	Trauma room	2	X-ray available
	Acute room	2	
	Barrier room	2	
	Treatment room	8	1 dedicated ear, nose, and throat.; 1 dedicated burns; 3 dedicated children
	Fast- track room	1	
	Plaster room	2	
	Diagnostic room	1	CT available
	Triage room	1	

Further, we distinguish different types of personnel at the GP post and the ED, each with their own tasks and responsibilities. At the GP post, we distinguish between four personnel types. The number of personnel which is present at the GP post, depends on the time of the day and the day of the week. Every day, there is one GP and one GP assistant on call, which can be called in case of sickness of the standard team or during extreme bustle.

Table 17
Types of personnel GP post

Organization	Personnel type	Task description
GP post	Receptionist	Receives patients upon arrival
	GP assistant	Answers phone, performs telephonic and physical triage
	General practitioner	Performs consultations, goes on visits
	Nurse practitioner	Treats specific patients groups

The number of personnel which is present at the ED, only depends on the time of the day. An overview of the standard team is given in Table 18. At the ED, there are two different trauma teams on call. On the basis of prior notification or presentation of a trauma patient, the appropriate trauma team is deployed. The basic trauma team can be called for the first care and treatment of a stable trauma patients at the ED. The trauma team can be called for the first care and treatment of unstable (multi-) trauma patients at the ED. The composition of those two teams are given in Table 19.

Table 18
Types of personnel ED

Organization	Personnel type	Task description
Emergency department	Receptionist	Receives patients upon arrival
	Triage nurse	Triages all self-referrals
	Coordinating nurse	Coordinates progress and execution of care and patient flow
	ED nurse	Nursing examination and care
	ED doctor	Treats unlabeled patients
	Co-assistant	Performs medical procedures under supervision of a resident
	Resident	Treats labeled patients and provides instructions regarding diagnosis, medication, treatment, and admission
	Medical specialist	Responsible for medical care provided at the ED by the resident of his specialty
	Department assistant	Performs supportive tasks
	Diagnostic employee	External staff types who comes to the ED to perform diagnostic tests

Table 19
Composition trauma teams

Basic trauma team	**Trauma team**
A(N)IO surgery/ orthopedics	Basic trauma team
1 ED nurse	1 (trauma) surgeon and 1 orthopedic surgeon (if on call)
1 laboratory technician radiology	Older year AIO (surgery/orthopedics)
1 technician clinical chemistry	2nd ED nurse
	Anesthesiologist and anesthesia assistant
	Radiologist and resident radiology
	CT technician

3.5 Sub processes at the NIP

Section 3.1 gave an overview of the paths a patient can go through at the NIP. These paths consist of several sub processes, each with a specific duration. The duration of a number of the sub processes is dependent on certain factors, for example the staff member that performs the task. In this section, we describe the various sub processes and we determine the duration of these sub processes.

Figure 4 shows all the possible paths through a NIP, with the process steps. Some of these processes need further explanation. Consultation at the GP post is generally carried out by a GP. However, three weekends a month a nurse practitioner (NP) is present at the post. A NP treats patients with specific characteristics. Consultation by a GP takes on average less time than consultation by a NP (ten versus fifteen minutes).

Only a GP can visit a patient at home. During the execution of this task, the GP is not present at the GP post. To arrive at the patients' home, the GP uses a car with a specialized chauffeur. Generally, there is one car available, only on Saturday and Sunday between 12 pm and 18 pm there are two cars available.

An ED consult consists of three steps: anamnesis, diagnostics, and treatment. For these sub-steps there are several options. In the remainder of this section we describe these options. An overview is given in Figure 18. The first step, anamnesis, can be performed by an ED nurse, an ED doctor, or by a resident. The resident helps all labeled patients. Labeled patients are all patients who are referred to a given specialism by, for example, a GP or a (external) specialist. These patients will be helped by a resident of that specialization. All unlabeled patients are first seen by an ED doctor. Unlabeled patients are patients who are not referred to a given specialism and includes all self-referrals at the ED and all patients who are brought to the ED by ambulance, helicopter, or by the police. The time anamnesis takes does not depend on the staff member that performs this process.

The next step is diagnosis. At the ED, various types of diagnostic tests can be requested/ performed. The most common diagnostic tests are X-ray, lab research, and computed tomography (CT). Other diagnostic tests are ultrasound, or electrocardiography (ECG). In the design of the new hospital, one can perform or request the diagnostic test in the following ways:

- Two devices for making X-rays are available, one at each trauma room. In first instance, these devices are used for the (multi-) trauma patients at the ED. However, when it is quiet this resource can also be used for non-trauma patients that enter the ED. If this device is not available, these patients are send to the ED/X-ray department, adjacent to the ED. Making x-rays is performed by a diagnostic employee.
- Lab research can be requested by a resident or by a medical specialist. In most cases, a diagnostic employee from the laboratory department comes to the ED to carry out the research.
- One device for making ultrasounds is available at the ED. This device can be used at every room, because in every room a dedicated connector is available.
- A patient can undergo a CT scan at the ED. A CT device is available in the diagnostic room, situated between the two trauma rooms. For this diagnostic test, a diagnostic employee comes to the ED.

– ECG equipment is not available at the ED. If a patient needs an ECG, this can be requested at the cardiac technician, or at the after-hours team leader. A diagnostic employee from the cardiac department is then send to the ED to perform the ECG.

The probability that a certain diagnostic test is requested depends on the treatment group of the patient, and is independent from the probability that other types of diagnostic tests are requested. Furthermore, the amount of diagnostic tests that is requested of a certain type is dependent on the treatment group. The probabilities and the average number of requests of a certain diagnostic test per treatment group are given in Appendix J.

The third step of an ED consult is treatment. In most cases, the patient is first treated by a resident. However, in some cases a medical specialist is called for further diagnosis and/or treatment of the patient. We assume that the probability that a medical specialist is called is dependent on the urgency of the patient. We assume that the duration of treatment is dependent on two variables: the treatment group and the treating doctor. The chance on calling a medical specialist is given in Appendix I, the duration of treatment is given in Appendix K.

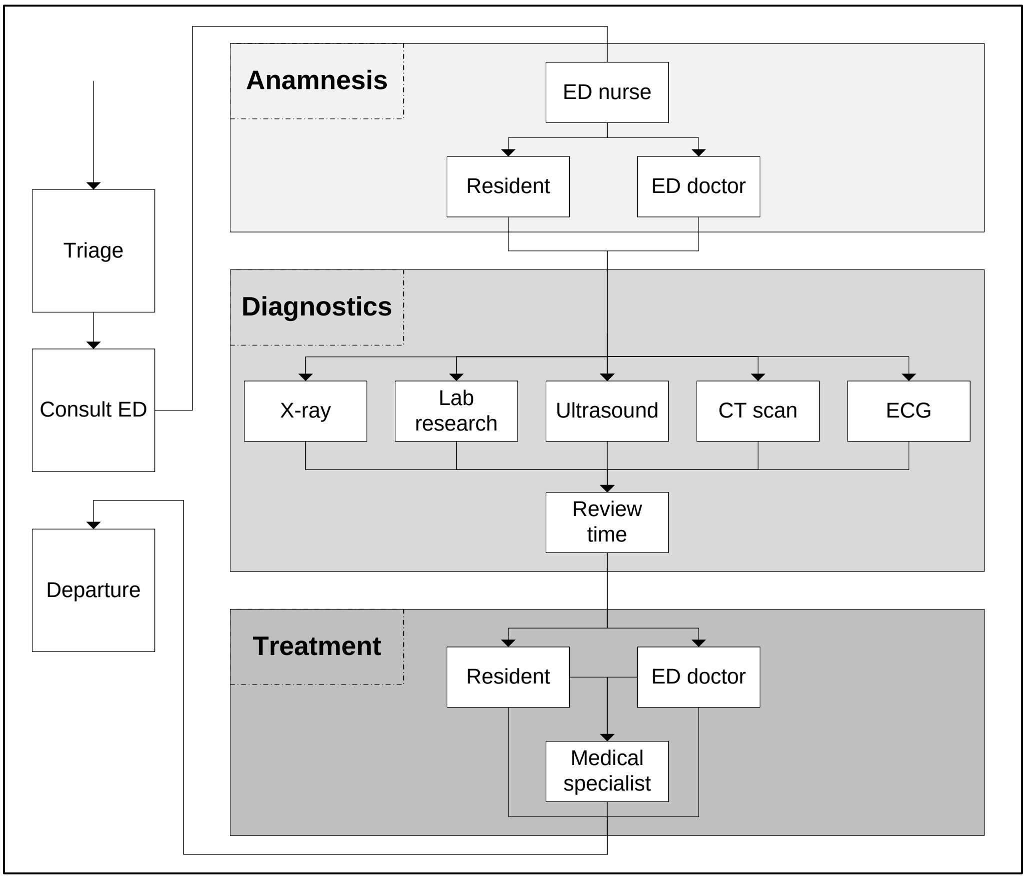


Figure 18

Processes ED

3.5.1 Sub processes vs. resource availability

In previous sections, we made a distinction between several rooms, personnel, and processes. Not every process can be performed in every room, and not every process can be performed by all types of personnel. Table 20 gives an overview of what tasks may be performed by whom and where, and what extra resource is needed.

Table 20
Processes vs. personnel and rooms

What	Task	Personnel	Room	Resource
Processes GP post	Telephonic triage	GP assistant	Call center	-
	Physical triage	GP assistant	Triage room GP post	-
	Consultation	GP; nurse practitioner	Consultation room; treatment room	-
	Visit	GP	-	Car GP post
Processes ED	Triage	Triage nurse	Triage room ED	-
	Anamnesis ED nurse	ED nurse	Trauma room; acute room; treatment room	-
	Anamnesis resident	ED doctor; resident; medical specialist	Trauma room; acute room; treatment room	-
	Plaster	ED nurse	Plaster room	-
	Treatment	ED doctor; resident; medical specialist	Trauma room; acute room; treatment room	-
Diagnostics ED	Lab research	Diagnostic employee	Trauma room; acute room; treatment room	-
	Ultrasound	Diagnostic employee	Trauma room; acute room; treatment room	Ultrasound equipment
	X-ray	Diagnostic employee	Trauma room; X-ray department	X-ray equipment
	CT scan	Diagnostic employee	Diagnostic room	CT
	ECG	Diagnostic employee	Trauma room; acute room; treatment room	ECG
	Review lab research	ED doctor; resident; medical specialist	-	-
	Review ultrasound	ED doctor; resident; medical specialist	-	-
	Review X-ray	ED doctor; resident; medical specialist	-	-
	Review CT scan	ED doctor; resident; medical specialist	-	-

3.6 From NIP to IEP

When the stakeholders of the ED and the GP post decide to move to an integrated emergency post (IEP), a number of things will change. This section gives an overview of the changes that occur.

When moving to an IEP, self-referrals can no longer directly go to the ED. All self-referrals will be seen at a common triage point, where a professional decides whether the patient goes to the GP post or to the ED. As a result of this, the paths through the ED and the GP post will change. The new situation can be modeled as given in Figure 19. This situation differs at some points from the situation which is described in Section 3.1. The most important change is that path A1 (self-referral ED – ED) is replaced by self-referral – physical triage – ED. In line with this, all self-referrals GP post and self-referrals ED are replaced by “self-referral”.

In the new situation, all self-referrals register at the same point and are triaged in the same way. Therefore, the former processes “physical triage GP post” and “physical triage ED” are now merged into the process “physical triage”. The process steps after telephonic triage and the remaining process steps after referral to the GP post or the ED will not change. A description of the paths through the IEP is given in Appendix M.

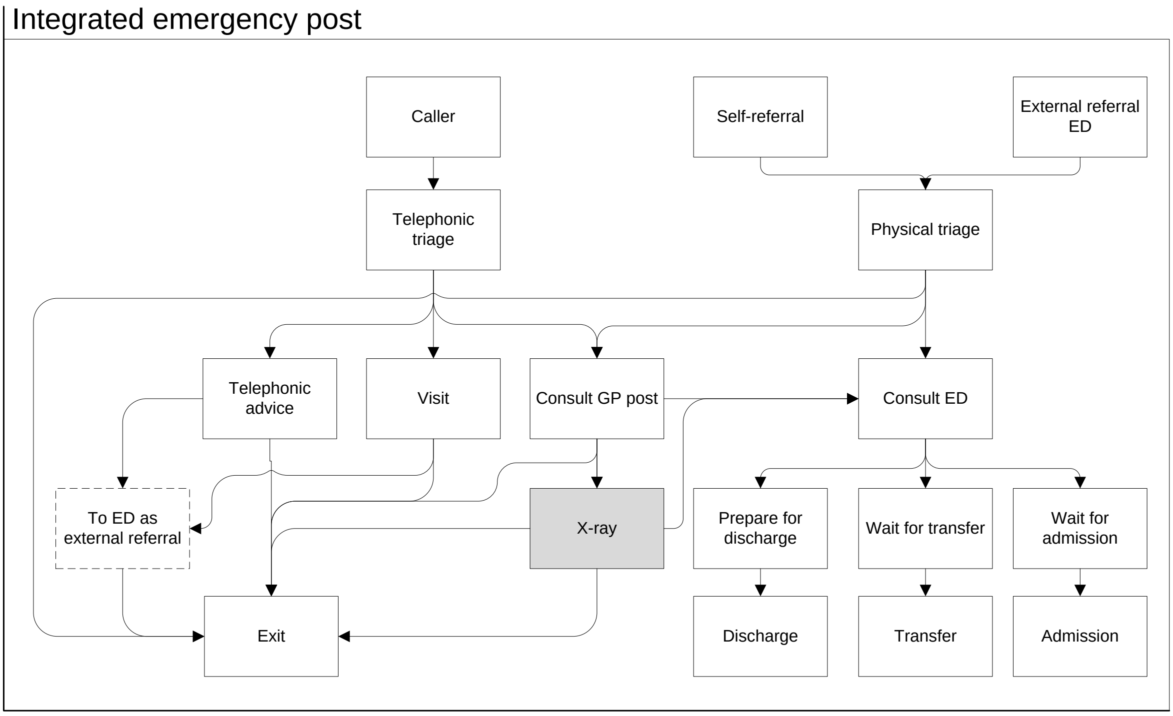


Figure 19
Flowchart integrated emergency post

At the common triage point, it is determined whether a patient is directly sent to the ED or if this patient is (first) seen by a GP. We assume that all patients who came to the ED as self-referral in the non-integrated situation, will also walk-in as self-referral in the integrated situation. Consequently, these patients can only follow path A1, A2, and A3 (respectively: self-referral to ED, self-referral to home, and self-referral to consult GP post) of the paths through the IEP.

We expect that, of all the self-referrals at the ED in the non-integrated situation, a large part will not be seen at the ED in the integrated situation. We cannot determine the exact percentage of all self-referrals that eventually ends up at the ED in the integrated situation, but we assume that a good estimate can be made based on expert opinion. Table 21 gives an estimate of the patients that are still referred to the ED in the integrated situation. This estimate is based on the urgency of the patient.

Table 21
Estimate of fraction of self-referrals that are referred to the ED in the IEP

	Urgency				
	Red	Orange	Yellow	Green	Blue
To ED	100%	90%	70%	50%	0%
Stay at GP post	0%	10%	30%	50%	100%

Now that we know the percentage of self-referrals that are referred to the ED in the new situation, we have to estimate the number of self-referrals that go through path A1, A2 or A3. This is important, because the patients that follow path A3 get a consult at the GP post and therefore have a higher influence on the processes that take place at the GP post than the patients who follow path A1 or A2. These patients only have triage at the GP post and thereafter do not longer affect the processes at the GP post.

In the determination of the number of patients that follow a certain path at the ED, we have to make a number of assumptions. These assumptions are all based on expert opinion.

- All red self-referrals will be referred to the ED in the integrated situation. These patients will be referred directly after triage, they do not get a consult at the GP post. So, they all follow path A1.
- None of the orange self-referrals is sent home directly after triage at the IEP (path A2). Of all the orange patients that are referred to the ED in the integrated situation, approximately (2/3) is directly sent to the ED (path A1), the rest goes through path B3 or B4 (equally). The remainder of the patients that stay at the GP post is equally distributed over the paths B1 and B2.
- All the yellow self-referrals that are sent to the ED in the integrated situation, are equally distributed over the paths A1, B3, and B4. The remainder of the yellow self-referrals that stay at the GP post are equally distributed over the paths A2, B1, and B2.
- Of the green self-referrals that are sent to the ED, no one is sent directly after triage (path A2), but they all go through path B3 and B4 (equally). The green self-referrals that stay at the GP post in the integrated situation are equally distributed over the paths A1, B1, and B2.
- None of the blue self-referrals is referred to the ED in the integrated situation. Furthermore, they do not get an appointment at the GP post. The only path they can go through is path A2.

A detailed description of the calculation of the amount of patients per path is given in Appendix N. Note that all patients that follow path A3, also follow a certain B-path. The amount of patients that go through path A3 is equal to the sum of the patients that follow a certain B-path. Another assumptions that have to be made concerns the GP post urgency that former ED self-referrals receive in the integrated situation. In this, we assume a one to one transitioning, as shown in Table 22. Former red ED self-referrals receive an U1 urgency at the GP post and former blue ED self-referrals receive an U5 urgency at the GP post.

Table 22
Assigning a GP post urgency to former ED self-referrals

Former ED urgency	**Assigned to GP post urgency**
Red	U1
Orange	U2
Yellow	U3
Green	U4
Blue	U5

The increased number of patients that arrive at the GP post in the integrated situation, will affect the number of patient that follow a certain path at the GP post and thereby also the probability of passing a particular path. The adjusted probabilities of passing a certain path are given in Appendix M. Furthermore, it will affect the probability of the arrival of GP post urgency u during time interval t. Therefore, these probabilities are recalculated, the results are also shown in Appendix M.

3.7 Summary

In this chapter, we analyzed the current delivery of out-of-hours care in Enschede. We described how a patient can enter, can move through, and can leave the NIP (the paths through a NIP). Additionally, we proposed a formula which we use to calculate the number of arrivals at hour *h*, at day *d*, and in week *w*. Based on historical data analysis, we calculated the values of α_h, β_d, and γ_w. Then, we described on basis of which variables we can distinguish the patients. We mentioned urgency and treatment group. Subsequently, we analyzed if dependencies exists between the variables time, path, urgency, and treatment group.

Furthermore, we analyzed what resources are used at the NIP. We made a distinction between rooms, staff, and additional resources (such as diagnostic equipment). Then, we have described what sub processes are performed at the NIP, and what sub process may be performed by whom and where, and what extra resource are needed.

At the end of this chapter, we described what changes take place when moving to an IEP. The major change is that self-referrals can no longer directly go to the ED, but they sign up at one common counter. Furthermore, we made assumptions on the number of self-referrals that still end up at the ED in the integrated situation.

4 Conceptual model

In the previous chapter, the analysis of the processes that take place at the ED and the GP post is described. We now have to correctly translate this into a conceptual model in order to simulate the processes at the ED and the GP post of Enschede. This chapter describes how the assumptions made are reflected into the simulation model and how the model is built. Furthermore, we describe where the situation of Enschede corresponds and where it differs from the situation in Almelo, the setting on which the existing simulation model is based. Additionally, we describe how the identified differences are reflected in the model. With *the existing simulation model*, we refer to the simulation model that is used in Almelo. With *the new simulation model*, we refer to the simulation model that will be used in Enschede.

4.1 Model explanation

In this section, we describe the basic structure on which the simulation model is based. First, we describe the way in which way the patient variables are assigned to a patient, after which the construction of the simulation model is described.

4.1.1 Creating patients

In Section 3.2, we described the analysis of the arrival processes at the GP post and the ED. Statistical distributions are determined to reflect the variability in the arrivals. The simulation model uses these statistical distributions to determine the number of arrivals during a specific time interval. At the arrival of a patient, the several patient related variables are assigned to the patient. Figure 20 shows how the patient variables are allocated to the patients in the new simulation model. These dependencies are based on the dependencies as proposed by Mes & Bruens (2012).

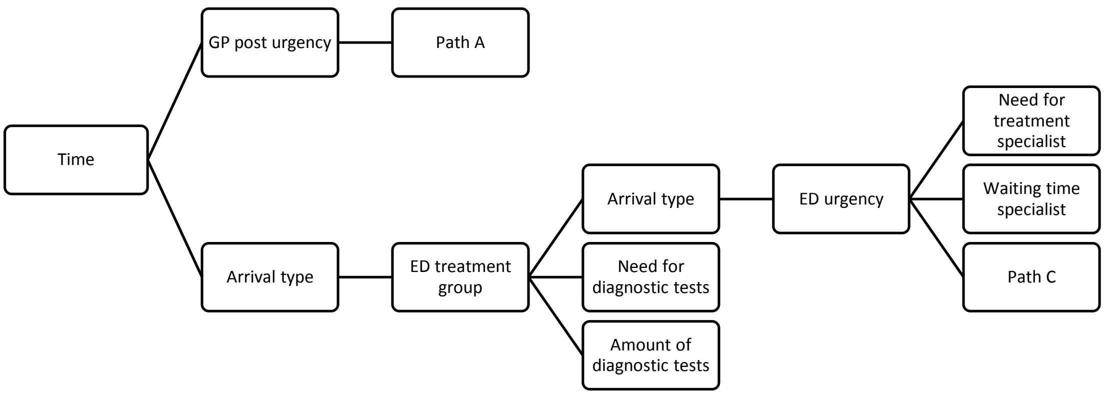


Figure 20
Allocation of patient variables in the new model

At the creation of a patient, a number of steps are taken:

- For a GP post arrival, a GP post urgency is determined, depending on the time of arrival of the patient.
- Depending on the GP post urgency, the A-path of the patient is determined.

- If the last step of the A path is *consult GP post*, it is determined which path the patient goes through at the GP post (path B). The probability of passing a certain B-path is independent of other variables, and is therefore not shown in Figure 20.
- For every ED arrival, an ED treatment group is determined. This ED treatment group is dependent on the time of arrival of the patient and on the arrival type of the patient.
- Depending on the arrival type, the ED urgency is determined. For external referrals and for self-referrals this is dependent on the treatment group to which the patients is assigned. For GP post referrals this ED urgency is related to the GP post urgency of the patient. The probabilities are given in Table 76 till Table 75 in Appendix O.
- Depending on the ED urgency, it is determined whether a specialist is needed for the treatment. If the specialist has to come to the ED, the waiting time on the specialist is also dependent on the ED urgency.
- Depending on the ED urgency, the way of leaving the ED is determined (C-path).
- Depending on the ED treatment group of the patient, it is determined whether diagnostic tests are required, and if so, which and how much.

4.1.2 Basic structure

Mes and Bruens (2012) described the simulation model on which this research is based. They proposed the basic structure of the simulation model, in which the events that trigger decisions and processes are identified. The basic structure is given in Figure 21. In this model, they distinguish between regular tasks, parallel tasks, and delay tasks. Regular tasks are requested by a patient and are mostly performed in one of the rooms at the GP post/ ED. Parallel tasks are tasks in which the patient does not need to be present and which can be carried out next to other tasks. Some steps require a preliminary task, due to which the step can be performed after a certain delay. These preliminary tasks are referred to as delay tasks.

The simulation model keeps track of all the patients that are in the system at that moment. Furthermore, it registers which staff is performing which task, for what patient, and which resources are used for that specific task. A task list is created in order to keep track of what tasks of which patients still need to be performed.

There are four events which can trigger new processes, see Figure 21.

- *A new hour starts* – The personnel schedules are checked every hour in the model. Some staff is sent to the hospital because their shift starts, other staff is sent home (after finishing the current task) because their shift ends. This results in an updated number of staff that is available for the execution of tasks. Furthermore, some resources are only available at certain hours (and on certain days). The model checks every hour which resources can be updated to available, and which to unavailable (after finishing the current task). After updating the staff, the task list procedure starts.
- *A new patient arrives* – Upon arrival of a new patient, the care pathway and all patient attributes are determined. The first step of the patients' care pathway is added to the task list and the task list procedure starts.
- *A task ends* – When a task ends, the models checks whether a parallel task is required. If a parallel task is necessary, the parallel task is added to the task list. Else, if the patient has not yet completed all the tasks on the care pathway, the next task is added to the task list and the task list procedure

starts. Otherwise, the patient is sent away. Furthermore, the model examines whether the resources used by the task become available again.

- *A delay task ends* – The model checks whether the resources used by the task can be updated to available again. If the patient has not yet completed all the tasks on the care pathway, the next task is added to the task list and the task list procedure starts. Otherwise, the patient is sent away. Furthermore, the model examines whether the resources used by the task become available again.

An important part of the basic structure is the *task list procedure*, displayed in bold in Figure 21. An overview of the task list procedure is given in Figure 22. The procedure starts with a check of all the tasks that are on the list. In previous research performed by Visser (2011), the tasks were prioritized based on urgency and waiting time. A high urgency patient always preceded a low urgency patient, and in case of equal urgencies, the longest waiting patient preceded. However, in practice, prioritization is based on urgency and waiting time simultaneously. If a low urgency patient has been waiting for a long time, he will precede a high urgency patient at some time. In the simulation model, this is realized as follows. For every urgency level, there is a maximum waiting time until the first resident contact (see Table 9). In the simulation model, the maximum waiting time is equal for every patient and is set at 240 minutes (the highest value in Table 9). When a patient enters the GP post or the ED, a fictitious waiting time is assigned to the patient, dependent on the urgency of the patient. The assigned waiting times per urgency level are given in Table 23. So, if a orange patient enters the ED, a fictituous waiting time of 230 minutes is assigned to the patient. The maximum allowable waiting time is 240 minutes, so the patient must be helped within 10 minutes (=240 – 230). This is equal to the maximum allowable waiting time for orange patients, given in Table 9. Thereafter, patients are not longer prioritized based on their urgency, but on their fictitious waiting time.

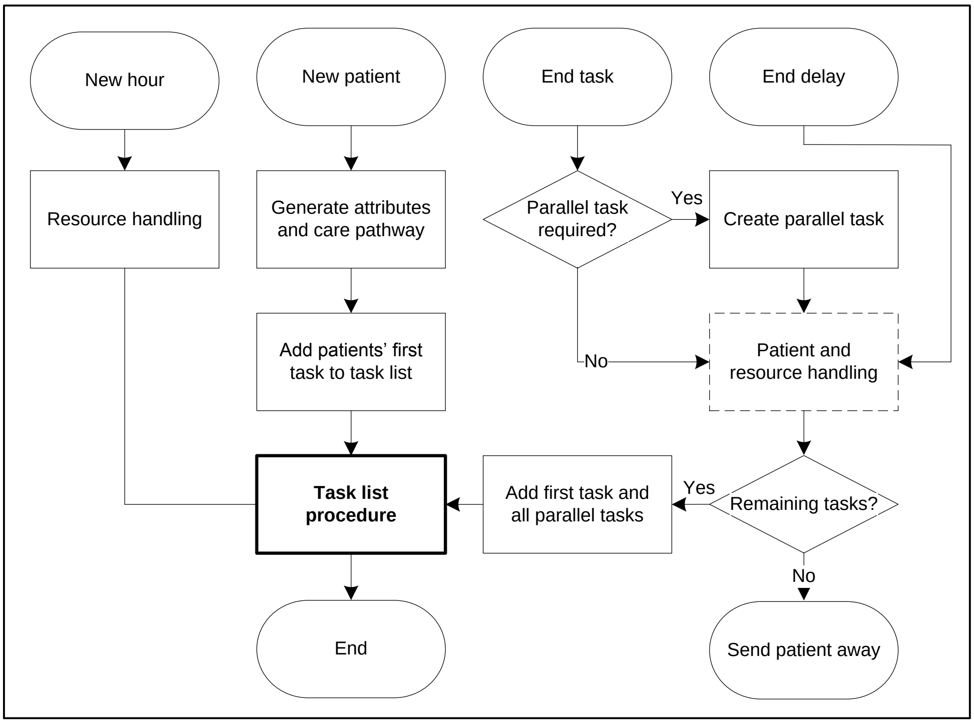


Figure 21
Basic structure simulation model (Mes & Bruens, 2012)

Table 23
Added waiting time simulation model

	Urgency	Added waiting time
GP post urgency	U1	225 minutes
	U2	180 minutes
	U3	60 minutes
	U4	0 minutes
	U5	0 minutes
ED urgency	Red	240 minutes
	Orange	230 minutes
	Yellow	180 minutes
	Green	120 minutes
	Blue	0 minutes

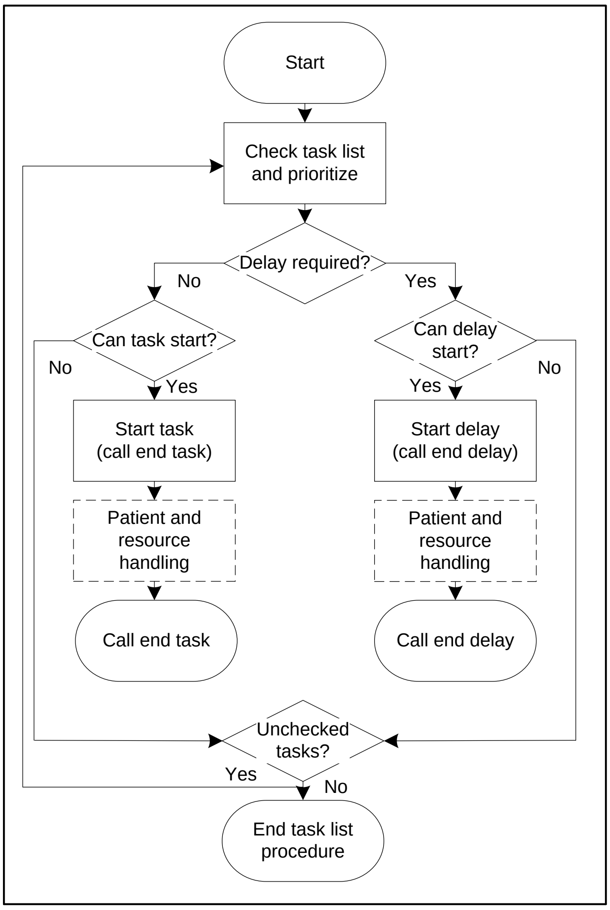


Figure 22
Task list procedure

In the next step of the task list procedure, it is determined whether a delay task needs to be performed before the next task can start. If no delay task needs to be performed, it is checked whether all resources are available to perform the following task. If this is not the case, the task stays on the task list and it is checked whether other tasks can be performed at that moment. If all resources are available, the task starts. The processing times of the tasks are given in Appendix K. After execution of the task, the procedure *end task* is called, and patient and resource handling starts.

If a delay task needs to be performed, it is determined whether all resources are available to perform the task. If not all resources are available, the task stays on the task list and it is checked whether other tasks can be performed at that moment. If all resources are available, the delay task starts. All tasks that need a delay task are given in Appendix L, with the corresponding duration of the delay. As mentioned earlier, in some cases, a medical specialist is called for the treatment of the patient at the ED, then the delay time is dependent on the urgency of the patient. These delay times are also given in Appendix L. After the duration of the delay, the procedure *end delay* is called, and patient and resource handling starts.

When the task list procedure ends, it is checked whether there are other unchecked tasks (see Figure 22). If so, the task list procedure starts again. If there are no other unchecked tasks, nothing happens until a new hour starts, a new patients arrives, or a (delay) task starts.

4.2 Adjustments

The existing simulation model contains a settings frame in which all input parameters are defined (a print screen of this frame is given in Appendix P). These input parameters are presented in different tables. Mes and Bruens (2012) stated that the existing simulation model is flexible and generic and that it can easily be adapted to other ED's as well as to other hospital departments. Because of this statement, we expect that we only have to change the input parameters in the tables in the settings frame in order to come to a correct simulation model that can be used at the ED/ GP post in Enschede. In this section, we discuss the differences in the input parameters between Almelo and Enschede and whether these changes can be implemented in the simulation model by only changing the tables in the settings frame, or that further changes need to be made. Where possible, comments will be made on how the model can be improved in order to make it (more) widely applicable.

The basic structure of the existing simulation model, described in the previous section, is straightly applicable for analysis in Enschede. However, the implementation of this basic structure is not directly applicable for analysis in Enschede. Therefore, we have to make several adjustments in the simulation model, varying in the degree of difficulty and the effort it takes to make the adjustment. We distinguish three types of adjustments:

- *Generic adjustments*: generic adjustments are modifications for which we only have to change the values of the input parameters in the settings frame. If modifications are needed in the format of a table, this will also be seen as a generic modification.
- *Non-generic adjustments*: non-generic adjustments are adjustments for which we need to make changes in the code of the simulation model (and if necessary, the associated changes in the settings frame).
- *Additions to the model*: additions to the model are additives to improve the existing model.

4.2.1 Generic modifications

In the existing simulation model, an IEP is used as starting point and assumptions were made on how patient arrived in the non-integrated situation. However, in this research, the opposite is the case. The starting point is a NIP, and we make assumptions on how patients will arrive in an IEP. This has consequences for the way in which we can insert the data of Enschede. In Figure 23, we see the difference between the two situations. In the situation of Almelo, the ED self-referrals are part of the GP post arrivals. In Enschede, the ED self-referrals are part of the ED arrivals. To overcome this problem, we calculate new hour-, day-, and week factors in which the ED self-referrals are part of the GP post arrivals. The calculation of these new factors is performed in the same way as described in Section 3.2. The results are given in Appendix Q.

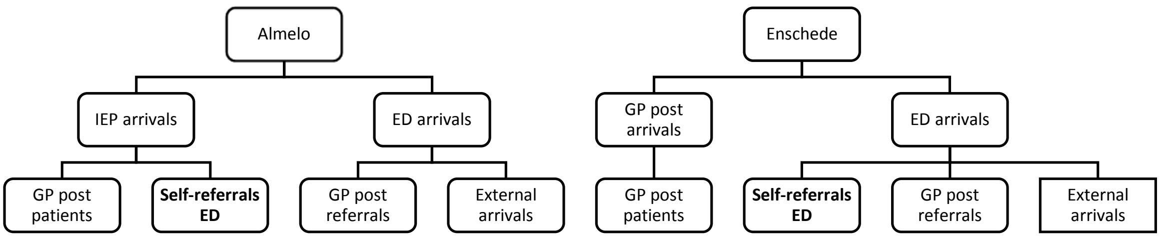


Figure 23
Difference between arrivals Almelo and Enschede

Another difference is that, at the IEP in Almelo, X-rays for GP post patients are made at the IEP. However, in Enschede, this process takes place at the X-ray department of the hospital. As a result, this process does not affect the course of events at the GP post. Furthermore, the number of patients who come back to the GP post for a follow-up consult (after X-ray) is negligible and will not be taken into account in this study. Therefore, the X-ray related processes are removed from the paths B2 and B3 in the simulation model. The adjusted paths are given in Table 80 in Appendix O.

The several (sub) processes in Enschede are to a large extent similar to the (sub) processes in Almelo. The duration of the X-ray related processes at the GP post are, in line with previous section, set equal to zero. In addition, the duration of the transfer related processes are also set equal to zero. Equating the duration of these processes to zero is basically double (because the probability of transfer is already zero and the X-ray related processes have been removed from the B-paths), but it is better than displaying an incorrect time. The processes are not deleted from the table, because they may be applicable in other settings. Furthermore, we added a waiting time for lab research and for an ECG. Of the other processes, we only changed the statistical distributions and the corresponding values.

The settings tables with the task-, and room distributions and the settings tables with the task-, and room priorities can simply be filled with the data of the ED/GP post in Enschede. We only need to adjust the headers for the changed staff types, the changed room types and the changed processes.

In the existing model, a distinction is made between ten “simulation groups”. These simulation groups correspond with our treatment groups, however, we distinguish twelve groups instead of ten. This is a minor change, but it will affect multiple tables. Because it only affects the size of the tables, this is considered as a generic modification. When adjusting the simulation groups, we saw that there was a reference in the code to the specific patient group S1, because this group of patients needs a plaster treatment at the ED. However, in order to keep the model generic, it is better to refer to a settings table (which can easily be changed) instead of to specific groups of patients in the code. This reference in the code would not cause any problems in this study, but it may happen in future research, so it is better to change this. Therefore, we add an extra column in the settings table in which the treatment groups are displayed, which shows whether that treatment group needs a plaster treatment. The information on the need for a plaster treatment per treatment group is from now on extracted from this table (by a minor change in the code).

As mentioned, the adjustment in the number of treatment groups affect multiple settings tables. These settings tables containing information about: the duration of ED treatment (resident or medical specialist), and information about the need, the number, the timing, and the location of diagnostic tests. After adjusting these settings tables for the adjusted amount of treatment groups in the new situation, the tables can simply be filled with data from Enschede. No further adjustments need to be made.

Besides the distinction in patient groups, the existing model also differentiates between several urgencies. The ED urgency as applied in Enschede are the same as in the existing model. However, there is a difference in GP post urgencies. The existing model distinguishes U1 till U4, the new model distinguish five urgency levels, U1 till U5. The urgency level U5 is added in multiple tables, including the table with the probabilities of passing a certain A-path given the GP post urgency.

Finally, there are some tables in the simulation model which need to be filled with the data of Enschede without any modification in the format of the settings table. The settings tables contain information about: the waiting times on a specialist per ED urgency, and on the probability of passing a certain B-path.

4.2.2 Non-generic modifications

The way in which the different variables are assigned to the patients and the dependencies between those variables differ between Almelo and Enschede. Figure 20 shows how the patient variables are allocated to the patient in the new model, which will be used in this simulation study. Figure 44 in Appendix O shows the way in which the patient variables were allocated to the patients in the existing model, used for the simulation study in Almelo. The first difference between the two models is that the new simulation model does not distinguish between days, with regard to the treatment group- and urgency distribution (for both the GP post and the ED). This is chosen, because we saw from Figure 9a, Figure 9c, and Figure 11a, that there is little or no variability in the treatment group distribution and urgency distribution between different days. For this reason, all the tables with data for a particular day have been deleted. For the determination of, for example, the treatment groups we can now retrieve the data from one table which is applicable to all days of the week.

Second, the existing model does not distinguish between arrival types in the determination of the treatment group of the patient. The new model will do this, because we saw from Figure 12 (Section 3.3.1) that the treatment group distribution differs per arrival type. Therefore, we introduce new tables in which the treatment group per arrival type and per time interval are written. This change also required adjustments in the code of the simulation model.

Third, the ED urgency in the new simulation model no longer depends on the time and the arrival type, but on the ED treatment group and the arrival type of the patient. This allows us to include the assumption that the urgency distributions in the treatment groups are different (see Figure 17). Time is taken into account indirectly, because the treatment group is dependent on time. This new introduced relation between ED urgency and ED treatment group also required adding new tables and adjusting the code of the simulation model.

Another change, related to the allocation of the patient variables, is that we use urgency as predictor of passing a certain C-path instead of treatment group. In Section 3.3.2, we described that the probability of passing a certain C-path is dependent on the urgency and on the treatment group of the patient. In our opinion, it is beneficial to the accuracy of the model to introduce a table in which for each treatment group and each urgency combined, the chance of passing a certain C-path is given. However, due to the missing data (previously described in Section 3.3.1), it is impossible to give a good estimate of these probabilities. Because we know the urgency of the patient with certainty, we choose *urgency* as predictor of passing a certain C-path. In order to implement this in the model, not only a change in the table was needed, but also a change in the code of the simulation model. In addition, in the existing simulation model, three options were considered to leave the ED: discharge, external admission or internal admission. We mentioned in Section 3.3.2, that transferred patients are not treated as a separate group. Therefore, we equate the probability of passing path C2 given the ED urgency (in the new table) to 0.00%.

Furthermore, in Enschede, there are other staff types than in Almelo, resulting in a changed staff table. After modification of the table, it appeared that there were references to specific staff types in the simulation code. As a result, several methods in the simulation model had to be adapted.

Furthermore, in the existing model, there were different staff schedules for Monday till Friday, for Saturday, and for Sunday. However, in Enschede, there are more than three staff schedules (Monday, Tuesday-Thursday, Friday, Saturday, and Sunday). Therefore, we had to add two staff schedules in the simulation model. This addition also required a change in the code of the simulation model, because there was a reference to the number of staff schedules in the code. In order to avoid a new adjustment in the code in future application of the model (in settings in which the number of staff schedules is again different), we made a staff schedule table for every day of the week. This requires changes to the code of the simulation model.

In the new simulation model, we introduce a new room type that will be used in the new hospital of MST, the so called fast-track room. This room can accommodate three patients. Only patients with low urgent complaints are treated in this room. The addition of a new room is in itself a generic adjustment. However, because only low urgent patients can be treated in the fast-track room, we have to add a new piece of code in the simulation model. This code ensures that the fast-track room is only a good option for green and blue patients (the other rooms do not have restrictions on urgency levels).

Another adjustment is a change in travel time between two GP visits. Previously, when a GP finished a visit at a patients' home, he went back to the hospital, where it was examined whether a new visit was on the task list. In case there was, the GP drove from the GP post to the next visit. Due to this structure, the travel time between the GP post and the patient was counted twice. However, it appears that a GP calls the GP post immediately after finishing a visit. He provides feedback on the visit, and checks whether he needs to go on a new home visit. If this is the case, the doctor directly goes to the new visit and does not return to the GP post first. Therefore, the travel time can be counted once.

In the existing simulation model, one can choose to simulate the whole day or to simulate only outside office hours. Because the ED is active throughout the whole day, it is possible that there are patients present at the ED at 17 pm, who still have to go through a number of steps of their care pathway. Therefore, there should be a correction for the number of patients at the ED at 17 pm if we only simulate outside office hours. By making use of Minitab, we determined the underlying statistical distribution of the number of ED patients at 17 pm. The best fitting distribution is the Weibull distribution, with a P-value of <0.010. The corresponding parameters are given in Table 24.

Table 24
Patients at 17h

Variable	Mean	Distribution	P1	P2	P3
Patients at 17h	12.6896	Weibull	0.0000	3.1052	14.1883

Weibull: P1 = minimal duration, P2 = shape, P3 = scale

When adjusting this in the model, we saw that a gamma distribution was hard coded for the number of patients at 17 pm. Because we assume a Weibull distribution, the number of patients at 17 pm has been determined in a wrong way. Therefore, a new piece of code has been implemented in the model, which first looks in the settings table which distribution is assumed for the number of patients at 17 pm, and then takes the appropriate parameters from the settings table.

4.2.3 Additions to the model

In the existing simulation model, the only resource a home visit requires is the staff type "GP". However, when a patient is visited at home by a GP, the GP also needs a car to reach the patient at home. These cars are specially equipped and are driven by a chauffeur, and there are only a limited number available cars. If this is not included in the simulation model, it may be that GPs are sent to a visit without an available car. Therefore, we introduce a new resource type: "Car GP post". During the weekdays, there is one car available for the GP visits. During the weekend between 12 pm and 18 pm, an extra car is deployed.

The existing simulation model distinguishes between several arrival types at the ED: GP post referrals, self-referrals, external arrivals, and patients arrived before 17 am. In the new model, a further distinction needs to be made between labeled and unlabeled patients, because 'labeled' and 'unlabeled' patients are treated by different staff types (see Section 3.5). The unlabeled patients will be helped by an ED doctor. The labeled patients will be helped by a resident of the specialty for which the patient is referred. Therefore, we added a new patient attribute, called *labeled*, to indicate whether the patient is labeled or unlabeled. Figure 24 shows how the arrival types are used in order to assign the patient a certain label.

Based on expert opinion, we assume that the probability that a certain patient is labeled or unlabeled is dependent on the urgency of the patient. Figure 46, Appendix O supports this assumption. Table 81 in the same appendix shows the probability of being labeled or unlabeled per urgency type. We add this table to the simulation model. The table is only used for the determination of the label of external arrivals. The ED self-referrals and the GP post referrals can be classified as respectively unlabeled and labeled with certainty (see Figure 24).

In addition, we add a table in which we determine the percentage of self-referrals and external arrivals at the ED at 17 pm. For the external arrivals, we again look what their probability is of having a certain label. Due to a small data set, this probability is based on historical fractions, independently from the urgency of the patient.

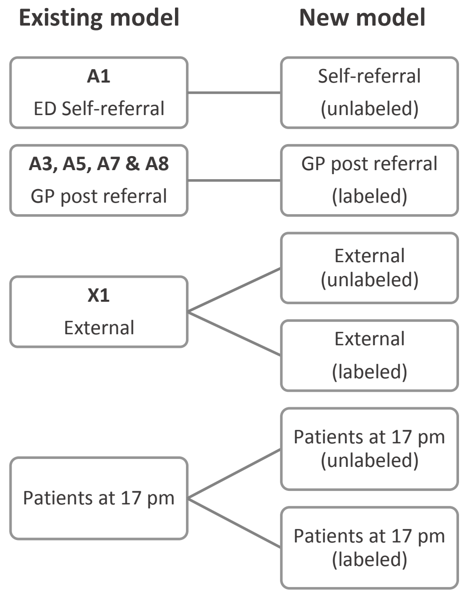


Figure 24
From arrival type to label

Subsequently, we have to realize in the model that labeled patients are actually seen by the resident of the specialty for which they are referred and that unlabeled patients are seen by an ED doctor. Therefore, we add a new settings table in which we describe per staff type which patients they may treat. An overview is given in Table 84, Appendix O. We add a code in the simulation model which first examines what label the patient has, after which he looks at the treatment group of the patient. If the label and the treatment group of the patient matches the authorization of the staff type, this staff type is allowed to treat the patient, see the flowchart in Figure 45, Appendix O.

In the existing simulation model, the likelihood of passing a certain A-path is dependent on the GP post urgency of the patient. This will also be used in the new simulation model, but there is one problem. At the starting point of Almelo (an IEP), the ED self-referrals are part of the GP post arrivals (see again Figure 23) and therefore had a GP post urgency from which they could deduce the A-path of the patient. However, at the starting point of Enschede (a NIP), the ED self-referrals are part of the ED arrivals and do not have a GP post urgency from which we can deduce the A-path of the patient. This is solved by converting the ED urgency of former ED self-referrals to a GP post urgency and to an A-path, when simulating an IEP (this is described in Section 3.6 and Appendix N). We can also apply this method in simulating the NIP, but we prefer that these patients are directly sent to the ED, without them getting a GP post urgency because we cannot determine this with certainty. What we do know is that the self-referrals follow path A1 (see Table 7). Therefore, we add a new settings table to the simulation model in which the amount of self-referrals is given as percentage of all GP post arrivals. If a patient is created in the new simulation model, it is determined on the basis of this ratio whether the patient is a self-referral. The ratios are given in Table 83, Appendix O. We add a code in the simulation model which examines whether the patient is an ED self-referral. If this is the case, the patient gets GP post urgency “x” (not applicable) and A-path A1. If the patient is not an ED self-referral, the GP post urgency is dependent on the time and the A-path is dependent on the GP post urgency, see Figure 25. The probabilities on passing a certain A-path given the GP post urgency is different for the NIP and the IEP and can be respectively found in Table 59, Appendix I and in Table 68, Appendix M.

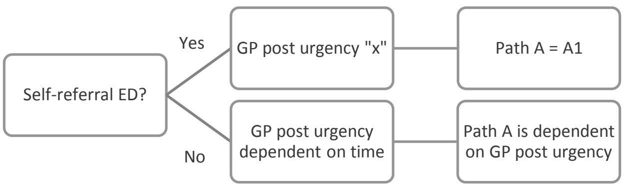


Figure 25
GP post urgency and A-path ED self-referrals

According to professionals from the ED, the duration of specific diagnostic tests is dependent on the ED urgency of the patient. For example, the duration of an ultrasound for a patient with ED urgency *red* is half of the normal length of an ultrasound. For this reason, we add a new settings table in which we can indicate the duration of a diagnostic test for a given urgency. A value of smaller than one in the table indicates a duration shorter than normal, a value of one indicates a duration equal to normal, and a value of greater than one indicates a duration longer than normal.

Finally, we add a new hospital map to the simulation model. This map shows the layout of the ED and GP post in the new hospital of Enschede.

4.3 Summary

This chapter started with a description of how patients are created in the simulation model and how the patient variables are assigned to the patients in Section 4.1. A clear overview of this process is given in Figure 20. Furthermore, Section 4.1 described the basic structure of the simulation model. An overview of the basic structure is given in Figure 21. Section 4.2 described how the processes in Enschede differ from the processes in Almelo and how these differences are implemented in the simulation model. We distinguished between three types of adjustments: generic adjustments, non-generic adjustments, and additions to the model. Table 25 summarizes all the generic adjustments we made to the simulation model. In the third column, we mention if we added or removed something from the settings table, or if we adjusted the headers of the settings table.

Table 25
Overview generic adjustments simulation model

Adjustment	Concerns	Comments
Generic	Adjusted arrivals	-
	Location X-ray	X-ray processes removed from paths
	Extra processes	Added waiting time lab research Added waiting time ECG
	Duration processes	-
	Task division and prioritization	Adjusted headers for new staff types
	Room division and prioritization	Adjusted headers for new room types
	Extra treatment groups	Added extra treatment groups Added need for a plaster treatment
	Need, amount, and location diagnostic test	Adjusted for extra treatment groups
	Duration ED treatment resident or specialist	Adjusted for extra treatment groups
	Urgencies	Added one extra urgency
	Probability A-path per GP post urgency	Adjusted for extra urgency
	Probability B-path	-
	Waiting time specialist	-

Table 26 summarizes the non-generic adjustment we made to the simulation model. The third column mentions whether this topic is generic now. If it is, the adjustment does not need to be done again in future application of the simulation model (in other settings). Some adjustments are made to correctly model the dependencies between the variables in the situation of Enschede. These adjustments are implemented in the simulation model in a generic way and can be used in future research if the dependencies between the patient variables are equal to the situation in Enschede.

Table 26
Overview non-generic adjustments simulation model

Adjustment	Concerns	Is it generic now?
Non-generic	No day variability	Yes
	Treatment group dependent on arrival type	Yes
	ED urgency dependent on treatment group and arrival type	Yes
	C-path dependent on ED urgency	Yes
	Other staff types	No
	Staff schedules	Yes
	New room type	Yes
	Travel time GP visit	Yes
	Patients at 17 pm	Yes

Table 27 summarizes the additions we made to the simulation model. Some additions are only applicable to the situation in Enschede. This is displayed in the third column. Efforts have been made to implement the other additions, which are also applicable in other hospitals, in a generic way in the simulation model. The fourth column of Table 27 shows which additions are generic now.

Table 27
Overview additions to the simulation model

Adjustment	**Concerns**	**Applicable to other hospitals?**	**It is generic?**
Addition	Car GP post	Yes	Partly
	Label	No	-
	GP post urgency self-referrals	Yes	Yes
	Factor diagnostics	Yes	Yes
	Hospital map	No	-

5 Simulation model

This chapter provides an overview of the new simulation model in Section 5.1. The verification and validation of the new simulation model is given in Section 5.2 and 5.3.

5.1 Overview

The simulation model designed by Mes and Bruens (2012) was built in the software package Tecnomatix Plant Simulation version 10.1. The required adjustments are also done in this software package. A screen shot of the adjusted model is given in Figure 26.

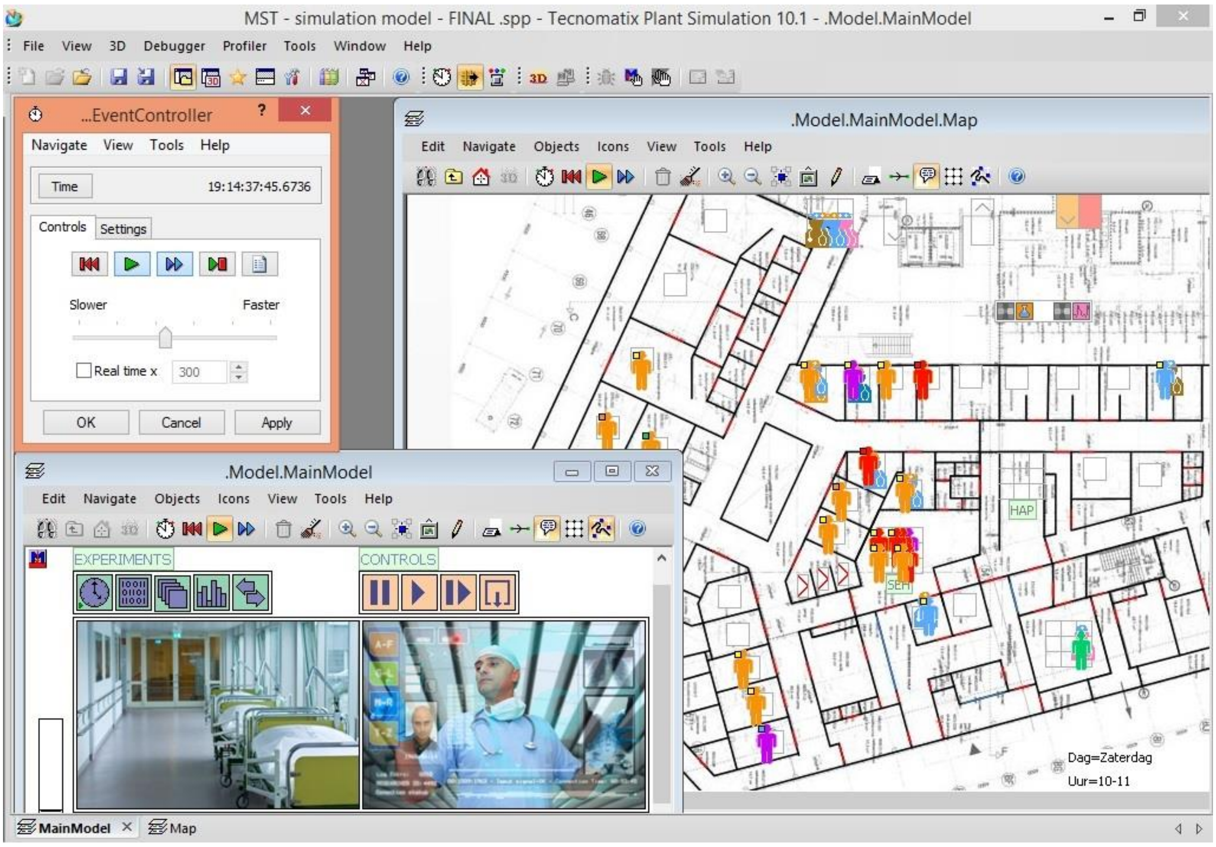


Figure 26
Print screen simulation model

In this figure, we see the map of the GP post and the ED in the new hospital. The left side shows the ED, the right side shows the GP post. We see that patients, staff, and resources come together in one room to perform several processes. As already mentioned in the previous chapter, the input of the simulation model is defined in settings tables in the simulation model (see Appendix P). While the simulation model runs, it keeps track of several patient characteristics, including: the paths a patient goes through, the urgency of the patient, the arrival times, and the length of stay (LOS). Furthermore, it records waiting times and process times of the processes that take place at the GP post or the ED.

Before we can use the results of the simulation model in decision making, we first have to check whether the assumptions are correctly translated into a computer program, and whether the simulation model is an accurate representation of the system. These two feedback loops are respectively called: verification and validation, and are described in the following two sections.

5.2 Verification

Law describes several techniques to verify a simulation model (see Section 2.1). The verification of the adjusted model that will be used in this research is performed by making use of some of these steps. First, the simulation model is debugged to check whether the model runs correctly. The existing simulation model was already checked and debugged by Borgman (2012) and van der Linde (2012). Therefore, we assume that the basic structure of the simulation model works correctly. The adjustments and additions we made to the model are all implemented one by one, and are debugged to check whether the simulation model actually did what we expected. If the simulation model did not what we expected, we adjusted the model and debugged it again. The final simulation model runs without errors. Second, the simulation model is reviewed by several persons. The existing simulation model was already reviewed by several persons. In addition, also the adjustments made to the simulation model are checked by several persons. The third technique we use for the verification of the simulation model is letting the simulation run under a variety of input settings. With this technique, we removed two errors from the simulation model. One related to the removal of external staff members, the other related to the storage of the output of the simulation model. The fourth technique we use for verification of the simulation model, is observing the animation of the simulation model. In this observation, we did not saw extraordinary behavior of the system.

The last technique we use for the verification of the simulation model is comparing the output of the simulation model with the input of the simulation model. The results are given in Table 28. We see that the percentages of arrivals does not differ largely with the input data (all differences are smaller than 5%). Furthermore, we analyzed whether the amount of patients following a certain path in the simulation model corresponds with the amount of patients following a certain path according to the data, the results are shown in Appendix R. No large differences were found between the output from the simulation model and the data. Also the number of patients with a certain urgency and/or ED treatment group are compared to the input data. These results are also shown in Appendix R. Again, we see no large differences between the output from the simulation model and the data. Therefore, we state that the assumptions we made are correctly translated into the simulation model.

Table 28
Comparison arrival input vs. arrival output simulation model; NIP

	GP post/ ED data (average 2012-2013)	**Model**	**Difference** (amount)	**Difference** (percentage)
GP post arrivals	47432	45657	-1775	-3.74%
Self-referrals ED	5656	5499	-157	-2.78%
GP post & X-ray referrals	4975	4823	-152	-3.06%
External referrals	4680	4860	180	3.86%
ED patients	15311	15182	-129	-0.84%
Total	57767	56016	-1751	-3.03%

In Section 3.6, we described that in the integrated situation, the former ED self-referrals can no longer directly go to the ED, but register at a common triage point. Due to this, the number of GP post arrivals and GP post referrals will increase, and the number of ED patients will decrease. The exact numbers of

GP post arrivals, GP post referrals, external referrals, and ED patients in the integrated situation are not yet known, but we made assumptions on this in Section 3.6. Using these assumptions, we can calculate the expected number of arrivals per arrival type in the integrated situation. These numbers are given in the second column of Table 29. Before we can use the results of the simulation model of the IEP, we have to know whether we implemented the IEP arrivals correctly in the simulation model. Therefore, we compare the output of the simulation model of the IEP with the expected number of arrivals at the IEP. In Table 29 we see that the percentages of arrivals in the IEP does not differ largely with the input data (all differences are smaller than 5%). Furthermore, we determined, for all former ED self-referrals, which GP post urgency they receive and through which path they go at the GP post in the integrated situation. Also these amount are compared with the output of the simulation model, see Table 92 till Table 94 in Appendix R. Again, we see no large differences between the output of the simulation model of the IEP and the data. Therefore, we state that the assumptions for the IEP are correctly translated into the simulation model.

Table 29

Comparison arrival input vs. arrival output simulation model; IEP

	GP post/ ED data (average 2012-2013)	**Model**	**Difference** (amount)	**Difference** (percentage)
GP post arrivals	53088	51330	-1758	-3.31%
GP post & X-ray referrals	8232	7976	-256	-3.11%
External referrals	4680	4864	184	3.94%
ED patients	12911	12840	-71	-0.55%
Total	57767	56194	-1573	-2.72%

5.3 Validation

In this section, the validation process is described. Law describes several techniques to validate a simulation model (see Section 2.1). We use some of these steps to validate the adjusted model which will be used in this research. First, we collected high-quality information and data on the system. We made use of historical data from the years 2012 and 2013. However, from a number of processes no historical data was available. The duration of these processes were estimated based on experts from the field.

Furthermore, during the executing of this research, there was a monthly meeting in which the assumptions made in the research were presented to stakeholders from both the GP post and the ED. The stakeholders had the opportunity to comment on the assumptions made. On basis of this, there adjustments were made in the simulation model, such that the simulation model gives a better representation of the reality. Besides, the model is more credible, because the stakeholders understand and accept the simulation model.

Another technique to validate the simulation model is to validate the components of the simulation model. To perform this step, we prefer to validate the waiting times of the simulation model. However, due to limited data, we cannot calculate an average waiting time based on the data of the ED. The only waiting time we can calculate it the waiting time till triage at the ED. In Table 30, we see the results. Based on this, we assume that the simulated waiting times at the ED correspond to reality. Furthermore, we would like to validate the waiting times at the GP post. However, the only times available to use are the arrival times and the authorization times. The time of the start of the treatment is not registered, due to which we cannot calculate the waiting time till a GP post consult.

Table 30
Waiting times ED

	Data *(minutes)*	**Model** *(minutes)*
Waiting time triage ED	5.10	4.60

Finally, Law describes the validation of the output from the overall simulation model as technique to validate a simulation model. In Table 31, one can see the overall output of the simulation model with regard to the LOS of ED patients. Despite the adjustments to the simulation model (described in previous section), the LOS of the patients in the first output of the simulation model did not correspond with reality. To correct for this, we assume that the duration of treatment is not only treatment group dependent, but also urgency dependent. Therefore, we added a factor to the duration of treatment. A factor of smaller than one in the table indicates a duration shorter than normal, a factor of one indicates a duration equal to normal, and a factor of greater than one indicates a duration longer than normal. The factors are given in the last column of Table 31.

After addition of the factors, we see that the simulation output does not differ more than 5% from the data for almost all the ED urgencies. Remarkably, however, is the large difference between the LOS of blue patients in the simulation model and in the data. The blue patients are patients that, according to professionals, do not really belong to the ED. The maximum waiting times of these patients is therefore also long (240 minutes, see Table 14). In theory, these patients are treated after all the other patients are helped. This is also implemented in this way in the simulation model. However, in practice it appears that those patients are helped in between the other patients, due to which they do not have to wait so long, and they are quicker discharged from the ED. We did not implement this in the simulation model, because this routine is not formalized. Due to this, the blue patients in the simulation model are waiting longer and the LOS will be longer than in reality. In this study, we will ignore this difference, because blue patients are only 0.32% of the total ED population, concerning less than one arrival in a week. In addition, we set the factor for blue patients at 0.1, and the probability of requesting a diagnostic test is zero. Due to this, the treatment times of the blue patients will be minimal, and the total LOS will mainly consist of waiting time. Therefore, the overestimation of the LOS of the blue patients does not affect the course of events at the ED.

Table 31
Comparison length of stay data vs. model; ED

	Amount of patients		**Length of stay**			**Factor**
	n (amount)	**n** (percentage)	**Data** (minutes)	**Model*** (minutes)	**Difference** (percentage)	
Red	246	1.62%	130.56	133.65	2.37%	1.00
Orange	2220	14.64%	136.46	133.02	-2.52%	1.10
Yellow	6421	42.35%	142.05	139.67	-1.67%	1.25
Green	6226	41.06%	93.17	92.02	-1.23%	0.55
Blue	49	0.32%	42.80	71.00	65.90%	0.10
Average	*15162*	*100.00%*	*120.35*	*118.81*	*-1.28%*	-

* LOS after the use of the factors in the last column

In Table 32, one can see the overall output of the simulation model with regard to the LOS of GP post patients. Again, the output of the simulation model with regard to the LOS of GP post patients did not correspond to reality in the first simulation output. Therefore, we also assumed at the GP post, that the duration of treatment is dependent on urgency. This is also confirmed by stakeholders from the GP post. The factors are given in the last column of Table 32.

However, even after the use of the factors, there is still a discrepancy between the output of the simulation model and the data. In Table 32, one can see that the simulation model gives a lower value for the average LOS of GP post patients than in reality. After discussing these results with stakeholders from the GP post, we found out that this discrepancy has the following explanation. The times that are registered in the GP post data system on which we can base the LOS of the patient are: the arrival time and the authorization time. However, we face two problems with these times. First, the arrival time at the GP post displays the time that the patient registers at the counter of the GP post. However, the patient could show up earlier than his appointment time, due to which the patient is waiting longer than actually planned at the GP post (beyond the control of the employees from the GP post). As a result, the LOS of the patient will be longer than if the patient arrived at the appointed time. Second, the authorization time is the time on which the GP approves the treatment and then closes the treatment in the computer. This may be done at the end of a consult, but it may also be done if the patient is already gone. If this is done when the patient is already gone, it will result in a longer LOS than when this approval is given directly after the end of treatment. Both registered times are very useful for the purposes of data collection of the GP post. However, the use of these times in this research will lead to a higher value of the average LOS at the GP post than in reality. Because no other times are available on which we can base the average LOS, these time will nevertheless be used in this research to give a rough indication of the actual LOS.

So, an exact value of the average LOS of patients at the GP post is not available. But, we assumed that the data gives a higher value than the actual LOS of GP post patients (based on aforementioned reasons). Therefore, the lower value of the LOS at the GP post from the simulation model (in comparison with the data) can be well explained, and we assume that the current output of the simulation model is valid.

Table 32

Comparison length of stay data vs. model; GP post

	Amount of patients		**Length of stay**			**Factor**
	n (amount)	**n** (percentage)	**Data** (minutes)	**Model*** (minutes)	**Difference** (percentage)	
U1	654	1.43%	24.53	23.36	-4.75%	1.5
U2	4789	10.49%	31.71	25.83	-18.54%	1.5
U3	15676	34.34%	33.01	25.24	-23.54%	1.0
U4	12393	27.15%	31.71	30.74	-3.06%	0.75
U5	12140	26.59%	31.11	33.11	6.44%	0.75
Average	45652	100.00%	32.36	27.27	-15.72%	-

* LOS after the use of the factors in the last column

5.4 Summary

In this chapter, we gave an overview of the adjusted simulation model. Based on the steps of Law (2007), we verified and validated the adjusted simulation model. In the verification phase, we saw that the simulation model gives the correct values for the number of arrivals at the NIP. Furthermore, we saw that the distribution of patients over the paths at the NIP are also modeled correctly. In the validation phase, we concluded that the simulation model gives the correct output with regard to the average LOS at the GP post and the average LOS at the ED.

6 Experimental settings and results

This chapter starts with a description of the relevant key performance indicators (KPIs) for the GP post and the ED. We define which KPIs will be used to compare different scenarios. Furthermore, we describe in Section 6.2 the experimental design of this study, after which we describe the settings for running the experiments in Section 6.3. In Section 6.4, we present the results of the experiments, after which the robustness of these results is described in Section 6.5.

6.1 Performance indicators

In order to make a comparison between two (or more) settings (or interventions), it is important to determine relevant key performance indicators (KPIs). This section gives a brief description of previous studies in which KPIs of the ED and the GP post are identified. At the end of this section we will come up with the KPIs that will be used in this research.

Fransman, Hans, Snel, Verheij & Doggen (2011) performed a discrete choice experiment with best-worst scaling in order to quantify patient preferences for key attributes of out-of-hours emergency care. The most important attribute was waiting time, which was followed by the way of access to the medical facility, the type of caregiver, and the availability of information on the expected waiting time. As part of the same research project, Reinders (2012) has performed a stakeholder analysis of the emergency post in Almelo. The identified stakeholders have prioritized several KPIs. This prioritization showed that there are differences between stakeholders from the GP post and the ED. For example, employees from the GP post attach the most importance to the response time to emergency calls and the right urgency classification. Employees from the ED attach the most importance to the triage waiting times and the waiting time before the first resident contact. Waiting time was seen as an important KPI for both organizations.

In previous described studies, waiting time is defined as an important KPI for the patient, but also for the stakeholders from both organizations. In both described studies, waiting time is defined as the time between arrival of the patient and the first resident contact. We will also use this definition of waiting time. Besides, we expect that integration of the GP post and the ED not only affects the waiting times, but also the processing times. Therefore, we use the performance indicator length of stay (LOS), which is calculated by the sum of all waiting times and processing times, and hence reflects changes in both variables. The average LOS for GP post patients and ED patients are analyzed separately, making it easier to see the influences of changing the situation on both organizations.

6.2 Experimental design

In this section, we describe the experiments that will be performed with the validated simulation model. First, we simulate the basic scenario, in which the ED and the GP post are non-integrated. Second, we simulate the situation in which the ED and the GP post are integrated. By comparing these two situations, we can see the effect of integration when the two organizations continue to work in the same way.

In Enschede, the integration of the ED and the GP post will go along with the relocation to a newly built hospital. This has implications for the numbers of rooms at the ED. In the new construction of the hospital, there is one extra room in which only low urgent patients can be treated. In a so-called fast-track room, one can treat three patients. The addition of this room can be seen as an intervention, but in this situation the addition of the fast-track room will take place anyway, regardless of the choice of integration. This results in three situations: 1) NIP in the old hospital, 2) NIP in the new hospital, and 3) IEP in the new hospital. The non-integrated emergency post in the old hospital is used for validation of the input data. However, this is not a realistic situation in the future, because the relocation will take place anyway. Therefore, the non-integrated emergency post in the new hospital is used as basic scenario (see Table 33 for an overview).

Table 33
Preliminary runs

Experiment	Description	Scenario	Integrated	Fast-track room
1)	NIP – old hospital	Current situation	No	No
2)	NIP – new hospital	Basic scenario	No	Yes
3)	IEP – new hospital	Proposed scenario	Yes	Yes

Because we expect that integration alone will not lead to a decrease in the LOS at both organizations, we first analyze the exact results of integration alone. Based on these results, we can introduce further experiments. The results from the three described experiments are given in Table 34. We see that only moving to the new hospital without integrating the organizations (experiment 2), has no significant effect on the average LOS at both organizations. Integrating both organizations in the new hospital (experiment 3), has a negative significant effect on both organizations. This result holds when we compare experiment 3 with experiment 1, but also when we compare experiment 3 with experiment 2.

An increase in the LOS of the patients at the GP post is an expected outcome. In the integrated situation, the GP post has to deal with a lot more patients than in the non-integrated situation. Without changing the staffing levels, patients will have to wait longer, which has a negative effect on the LOS. However, through integration, the ED has to deal with less patients. A decrease in the LOS of ED patients would therefore be a logical outcome. However, the results from the experiment show the opposite. At first, this seems strange. However, a good explanation can be given for this increase in the LOS of ED patients. In Enschede, the ED doctor treats unlabeled patients and residents treat patients which are referred to their specialty. However, by integrating the GP post and the ED, the ratio unlabeled/ labeled patients at the ED changes. In the non-integrated situation, the ED self-referrals are unlabeled patients. However, in the integrated situation, the ED self-referrals sign up at a common counter, and not all ED self-referrals will end up at the ED. If they are referred, they arrive at the ED as GP post referrals and are therefore be seen as labeled patients. Due to this, the ED doctor has much less to do, and the residents are much busier. This will result in a longer waiting time for ED patients, and therefore in an increase in the LOS of these patients.

Table 34
Non-integrated vs. integrated

Experiment	Scenario	Concerns	Outcome	Compared to experiment 1		Compared to experiment 2	
			LOS (min)	*Δ LOS***	*P-value*	*Δ LOS***	*P-value*
Experiment 1	*Current situation*	*ED*	118.81	-	-	-	-
		GP post	12.28	-	-	-	-
Experiment 2	*Basic scenario*	*ED*	117.73	-0.91%	0.123	-	-
		GP post	12.27	-0.02%	0.985	-	-
Experiment 3	*Proposed scenario*	*ED*	154.46	30.00%	0.000*	31.20%	0.000*
		GP post	15.79	28.62%	0.000*	28.65%	0.000*

*Significant with α = 0.05;** Δ LOS = difference in LOS

Stakeholders from both the ED and the GP post are interested in the effects of integration on patients, and on the processes that take place at the ED and the GP post. Furthermore, they are interested in the way in which an integrated emergency post can be arranged such that the changed patient flow can be handled in at least the same manner as in the current scenario in terms of the average LOS at both organizations. Based on the interest of experts and on the results given in Table 34, we propose a number of interventions to evaluate.

- *Expanding the ED doctors' authorities* – in the current situation, the ED doctor is only authorized to treat unlabeled patients. However, in other hospitals, the ED doctor has more authorities. From the results of experiment 3, we saw that the situation in which the ED doctor is only authorized to treat unlabeled patients is unfavorable in an integrated situation. Therefore, we want to analyze the effect of expanding the ED doctors' authorities, by letting him treat also labeled patients.
- *Increase amount of staff at the GP post* – in the integrated situation, the GP post has to deal with more patients to triage and to treat as in the non-integrated situation. Therefore, a logical step would be to increase the amount of staff at the GP post. The GP post can add three staff types to treat patients:
  - *Adding one extra triage nurse at the GP post at every hour*
  - *Adding one nurse practitioner at every hour*
  - *Adding one general practitioner at every hour*
- *Using the same triage system* – the ED of MST will probably decide to use the same triage system as the GP post. Due to this, GP post referrals do not need to be triaged again at the ED. This has implications for the LOS of the patients at the ED.
- *ED and GP post make use of each other's rooms* – stakeholders from both organizations are interested in the impact of sharing each other's rooms during busy hours.

The interventions may take the values gives in Table 35. We want to analyze the impact of these interventions, but we also want to analyze whether there are interaction effects between the factors. In order to keep the total simulation time as short as possible, we first determine the impact of the interventions apart from each other. After the analysis of the impact of these interventions, we select the most promising ones. From these promising interventions, we want to know whether they interact with each other. Law (2007) describes a 2^k factorial design as a strategy which can measure interactions between two or more factors. A 2^k factorial design requires that we choose only two levels for each factor (see Table 35) and then let the simulation run at each of the 2^k possible factor-level combinations. From the promising interventions, we make such a 2^k factorial design. The way in which this factorial design is set up, is dependent of the results of the individual experiments and will therefore be described later in this chapter.

Table 35
Values of interventions

		Two levels	
		-	+
Experiment 4	*Expanding the ED doctors' authorities*	No	Yes
Experiment 5	*Adding one extra triage nurse*	No	Yes
Experiment 6	*Adding one nurse practitioner*	No	Yes
Experiment 7	*Adding one general practitioner*	No	Yes
Experiment 8	*Using the same triage system*	No	Yes
Experiment 9	*make use of each other's rooms*	No	Yes

6.3 Simulation settings

According to Law (2007), the way in which simulation experiments are designed and analyzed is dependent on the type of simulation. With regard to output analysis, Law distinguishes between two types of simulation, a terminating simulation and a non-terminating simulation. A terminating simulation is a simulation in which there is a natural event that ends the simulation run. A non-terminating simulation is a simulation in which there is no such natural end event. In this analysis, the NIP and the IEP is only analyzed outside office hours, which means that at the start of office hours, the simulation ends. So, there is a natural event that ends the simulation and therefore we can designate this simulation as a terminating simulation. However, the ED is open throughout the whole day, due to which it is possible that there are patients in the system at 5 pm. These patients can affect the behavior of the system, because they probably still have to go through a number of process steps and therefore require some resources. Therefore, we have to account for these patients. We can do this by using a warm-up period (i.e. during the office hours), but this will result in a longer simulation time, which is unfavorable. Therefore, we add a table in which we specify the number of patients at 5 pm in the system (with the corresponding parameters). Every day at 17 pm, we place, based on this statistical distribution, a number of patients in the system (see Section 4.2.2). Due to this, we do not need a warm-up period.

In order to estimate the mean of the LOS at the ED and the GP post, we have to perform a certain amount of replications of a certain experiment. From Section 3.2.2 and Section 3.2.3, we saw that the arrivals hours and the days are different in terms of the number of arrivals. However, we also saw that there is no seasonal effect and that the weeks are not different in terms of arrivals. Therefore, we can see a week as a replication for an experiment. The minimum amount of weeks we have to simulate in order to estimate the mean with a specified error of precision can be determined by making use of the sequential procedure, which is described in Appendix S. This procedures uses the following formula, described by Law (2007):

$$n^* = min\left\{ i \geq n \colon \frac{t_{n-1,1-\frac{\alpha}{2}}\sqrt{S^2(n)/n}}{\overline{X}(n)} < \ \gamma/(1+\gamma) \right\}$$

Operationalization of the variables in this formula is given in Appendix S. In order to determine the minimum number of replications required in this study, we run experiment 1 till 3 for one year. Based on these results, we estimated the mean with a relative error of 0.05 and a confidence interval of 95%. The minimum required number of replications per experiment is given in Table 36. We see that the highest value for the minimum required number of replications is 51. So, if we simulate every experiment for a whole year (52 weeks), we are sure that the estimated means have a 95% confidence interval.

Table 36
Number of replications

	Number of replications based on	
	ED LOS	*GP LOS*
Experiment 1	15	48
Experiment 2	7	44
Experiment 3	29	47

6.4 Results experiments and interaction effects

In this section, we analyze the effects of the interventions apart from each other, based on the average LOS at the GP post and the ED. The interventions that have a significant effect on at least one of the LOS of the organizations (compared to the proposed scenario) are combined to identify possible interaction effects.

First, we determine the effects of the interventions apart from each other. In Table 105, Appendix S, one can see the level of each intervention per experiment (- level or + level). The results of the experiments are shown in Table 37. In this table, we show the difference between the outcomes of the separate interventions and the proposed scenario (IEP in new hospital). The significant effects are marked with an asterisk. We see that adding a triage nurse at the GP post and sharing each other's rooms have no significant effect of the LOS of one of the organizations. The other experiments do have a significant effect on the LOS at one of the organizations. Expanding the ED doctors' authority and using the same triage system have a significant, positive on the average LOS at the ED. Remarkable is that using the same triage system also has a significant, negative effect on the LOS at the GP post. We cannot declare this, but it is merely an increase of 22 seconds. We will assign this phenomenon, despite the fact that the effect is significant, to coincidence. Adding a nurse practitioner (NP) or a general practitioner (GP) at the GP post both have a significant, positive effect on the LOS at the GP post. In addition, they also have a small, but significant, negative effect on the ED LOS. This may be, because patients are referred to the ED at another, busier time in the integrated situation, due to which they have to wait longer at the ED and the LOS will increase slightly.

Table 37
Results individual experiments compared to proposed scenario

	Emergency department			**GP post**			
	LOS	*Δ LOS***	*P-value*	*LOS*	*Δ LOS***	*P-value*	*Intervention*
Experiment 3	154.46	-	-	15.79	-	-	Proposed scenario
Experiment 4	111.65	-27.71%	0.000*	15.90	0.72%	0.532	ED authority
Experiment 5	153.65	-0.52%	0.464	15.51	-1.74%	0.124	Triage nurse GP post
Experiment 6	156.95	1.62%	0.025*	9.66	-38.83%	0.000*	Nurse practitioner
Experiment 7	157.43	1.93%	0.009*	8.59	-45.59%	0.000*	General practitioner
Experiment 8	148.03	-4.16%	0.000*	16.17	2.41%	0.040*	Same triage
Experiment 9	153.48	-0.63%	0.379	15.55	-1.52%	0.185	Share rooms

*Significant with α = 0.05;** Δ LOS = difference in LOS compared to experiment 3

Furthermore, we analyzed the difference between the outcomes of the separate interventions and the basic scenario (NIP in the new hospital). Table 38, shows the results. We see that expanding the ED doctors' authority has a significant, positive effect on the average LOS at the ED, and that adding a NP or a GP at the GP post has a significant, positive effect on the average LOS at the GP post. However, none of the separate interventions has a significant, positive effect on the LOS at both organizations compared to the basic scenario.

Table 38

Results individual experiments compared to basic scenario

	Emergency department			**GP post**			
	LOS	*Δ LOS***	*P-value*	*LOS*	*Δ LOS***	*P-value*	*Intervention*
Experiment 2	117.73	-	-	12.27	-	-	Basic scenario
Experiment 4	111.65	-5.16%	0.000*	15.90	29.58%	0.000*	ED authority
Experiment 5	153.65	30.51%	0.000*	15.51	26.41%	0.000*	Triage nurse GP post
Experiment 6	156.95	33.32%	0.000*	9.66	-21.30%	0.000*	Nurse practitioner
Experiment 7	157.43	33.72%	0.000*	8.59	-30.00%	0.000*	General practitioner
Experiment 8	148.03	25.74%	0.000*	16.17	31.75%	0.000*	Same triage
Experiment 9	153.48	30.37%	0.000*	15.55	26.70%	0.000*	Share rooms

*Significant with α = 0.05;** Δ LOS = difference in LOS compared to experiment 2

6.4.1 2^k factorial design

In Table 37, we see that the interventions with a significant effect on the LOS at one of the organizations are: expanding ED doctors' authority, adding a NP, adding a GP, and using the same triage system. We combine these interventions in a 2^k factorial design to identify possible interaction effects. The design matrix of the 2^k factorial design is given in Table 106 in Appendix S. An overview of the results of the experiments is given in Table 107 in Appendix S. Table 39 shows the results of the most promising experiments. Expanding the ED doctors' authority (experiment 4) is part of each of the most promising interventions. In addition, also the use of the same triage system (experiment 8) is part of most of these experiments. Figure 27, visually present the results of the most promising interventions compared to the proposed scenario. From this figure, we can easily see that experiment 22 leads to the largest decrease in the LOS at the ED, and that experiment 21 leads to the largest decrease in the LOS at the GP post.

Table 39

Most promising experiments compared to proposed scenario

	Emergency department			**GP post**			Combination of
	LOS	Δ LOS**	P-value	LOS	Δ LOS**	P-value	experiment(s)
Experiment 15	111.87	-27.57%	0.000*	9.53	-39.61%	0.000*	4, 6
Experiment 16	112.20	-27.36%	0.000*	8.49	-46.24%	0.000*	4, 7
Experiment 21	112.06	-27.45%	0.000*	7.65	-51.57%	0.000*	4, 6, 7
Experiment 22	105.04	-31.99%	0.000*	9.85	-37.59%	0.000*	4, 6, 8
Experiment 23	105.09	-31.96%	0.000*	8.26	-47.67%	0.000*	4, 7, 8
Experiment 25	105.10	-31.96%	0.000*	7.72	-51.08%	0.000*	4, 6, 7, 8

*Significant with α = 0.05;** Δ LOS = difference in LOS compared to experiment 3

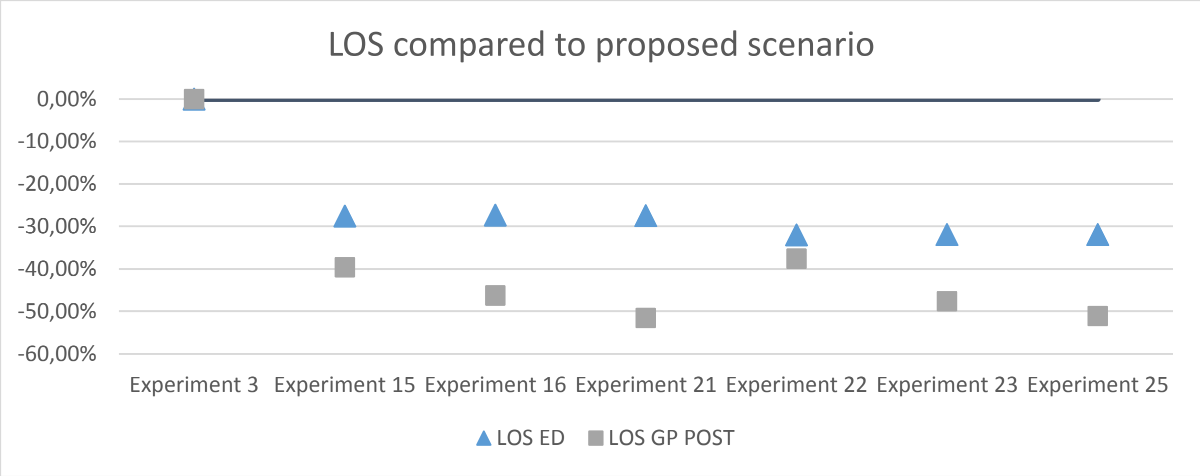


Figure 27
LOS compared to experiment 3

Furthermore, we compared the most promising interventions to the basic scenario. The results are given in Table 40, Figure 28 visually presents the results. We see that a combination of interventions does lead to significant, positive effects at both organizations, compared to the basic scenario.

Table 40
Most promising experiments compared to basic scenario

	Emergency department			**GP post**			Combination of experiment(s)
	LOS	Δ LOS**	P-value	LOS	Δ LOS**	P-value	
Experiment 15	111.87	-4.97%	0.000*	9.53	-22.31%	0.000*	4, 6
Experiment 16	112.20	-4.70%	0.000*	8.49	-30.85%	0.000*	4, 7
Experiment 21	112.06	-4.81%	0.000*	7.65	-37.69%	0.000*	4, 6, 7
Experiment 22	105.04	-10.77%	0.000*	9.85	-19.71%	0.000*	4, 6, 8
Experiment 23	105.09	-10.73%	0.000*	8.26	-32.68%	0.000*	4, 7, 8
Experiment 25	105.10	-10.73%	0.000*	7.72	-37.07%	0.000*	4, 6, 7, 8

*Significant with α = 0.05;** Δ LOS = difference in LOS compared to experiment 2

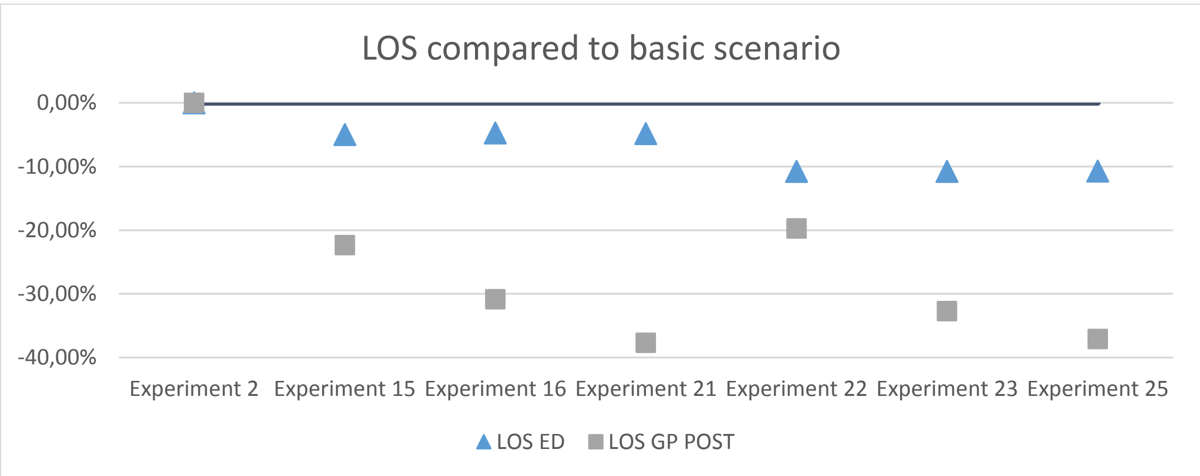


Figure 28
LOS compared to experiment 2

6.4.2 Selecting the best scenario

Next, we select the scenario that has in our opinion the most potential to succeed. However, this is difficult. We can base this decision on only the LOS at both organizations, but there are also other factors that must be taken into account (costs, for example). Although this study focusses on the LOS at the GP post and the ED, we can keep such factors in mind.

Expanding the ED doctors' authority is part of all most promising interventions. Furthermore, from Table 107 in Appendix S, we can see that the experiments with this intervention show a minimum decrease in the LOS at the ED of 27.36%. The experiments without this intervention, show a maximum decrease in the LOS at the ED of 4.16%. In addition, this changed division is commonly used in other hospitals and will not lead to additional costs. Given these findings, we find that expanding the ED doctors' authority should be implemented in the integrated situation anyway.

Furthermore, stakeholders from the ED were already planning to use the same triage system as the GP post, because they expect that it will have a positive effect on the processes at the ED. From the experiments, we see that the use of the same triage system indeed has a positive effect on the LOS at the ED. Therefore, using the same triage system should also be implemented in the new situation anyway.

Because of the previous choices, only experiment 22, 23, and 25 remain from the most promising experiments (given in Table 39). These experiments involve respectively: adding a NP at the GP post, adding a GP at the GP post, or adding a NP and a GP at the GP post. As said, experiment 25 will lead to the highest decrease in the LOS at the GP post. However, adding additional staff will, to a certain point, always lead to a decrease in the average LOS. Therefore, we need to consider whether the effects of adding extra staff will outweigh the costs of it. As said, the stakeholders are interested in the way in which an integrated emergency post can be arranged such that the changed patient flow can be handled in *at least* the same manner as in the current situation with regard to the average LOS. In Table 41, we see the difference in LOS at the GP post of experiment 22, 23, and 25 compared to the *current* situation. We see that in all experiments, the average LOS is already better than in the current situation. Adding two additional staff types will therefore be unnecessary and costly. Therefore, we have to choose between adding a NP or adding a GP. Adding a GP will result in a decrease in the average LOS at the GP post of 1.69 minutes (-16.17%) compared to adding a NP. However, stakeholders from the ED find that adding a NP is the best solution, because this is cheaper and already leads to a significant decrease in the LOS at the GP post compared to the current situation.

Table 41

Difference LOS GP post compared to current situation

	LOS GP post	**Δ LOS****	**Δ LOS****
	(minutes)	*(minutes)*	*(percentage)*
Experiment 1	12.28	-	-
Experiment 22	9.85	-2.43	-19.76%
Experiment 23	8.26	-4.02	-32.72%
Experiment 25	7.72	-4.56	-37.11%

** Δ LOS = difference in LOS compared to current situation

Based on previous arguments, we choose experiment 22 as most promising way of organizing an IEP in Enschede. This experiment involves: expanding the ED doctors' authority, using the same triage system, and adding a NP at the GP post.

6.5 Sensitivity analysis

In this section, we perform a sensitivity analysis to determine the impact of the assumption made in Section 3.6. This assumption concerns the amount of ED self-referrals that still end up at the ED in the integrated situation. All the experiments have been carried out on the basis of this assumption. Based on the results of these experiments, we argued that experiment 22 is chosen as best scenario. In this scenario, the average LOS at the ED decreases with 31.99%, and the average LOS at the GP post decreases with 37.59% compared to the IEP without interventions (IEP 3). On the basis of a sensitivity analysis, we examine whether these positive results also hold when we the percentage of ED self-referrals that eventually end up at the ED turn out to be different.

To perform a sensitivity analysis, we change the percentages of ED self-referrals that eventually end up at the ED per urgency one by one. The previously assumed probabilities are given in Table 21. The assumptions that all red ED self-referrals are referred to the ED in the integrated situation, and all blue ED self-referrals stay at the GP post in the integrated situation are considered as correct. Therefore, we do not perform a sensitivity analysis on these percentages. For the other ED urgencies orange, yellow, and green, we choose two levels for the analysis. First, we decrease the percentage of self-referrals that are send to the ED per urgency to 0%. Second, we increase the percentage of self-referrals that are send to the ED per urgency to 100%. The levels are given in Table 42. In order to determine the effects correctly, we can only change one value per sensitivity analysis.

Table 42
Levels for sensitivity analysis

Concerns ED urgency	Number	Level	Stay at GP post	Send to ED
Orange	*Sensitivity 1*	Low	100%	0%
	Sensitivity 2	High	0%	100%
Yellow	*Sensitivity 3*	Low	100%	0%
	Sensitivity 4	High	0%	100%
Green	*Sensitivity 5*	Low	100%	0%
	Sensitivity 6	High	0%	100%

In this sensitivity analysis, we compare the IEP with interventions (IEP 22) with three other scenarios:

- *The basic scenario (NIP 2):* to analyze whether integration with interventions leads to a lower LOS at both organizations than the basic scenario for every level of the sensitivity analysis.
- *The proposed scenario (IEP 3)*: to analyze whether integration with interventions leads to a lower LOS at both organizations than integration without interventions for every level of the sensitivity analysis.
- *The basic scenario with interventions (NIP 44):* to analyze whether integration with interventions leads to a lower LOS at both organizations than no integration with the same interventions for every levels of the sensitivity analysis.

The results of the sensitivity analyses are shown in Figure 29 till Figure 34. It can be seen that, in the situation of the IEP, the average LOS at the ED increases when we refer more patients to the ED. This is an expected effect, because there are simply more patients to be treated. However, such an increase in the average LOS at the ED cannot be seen from the results when referring more patients to the ED in the situation of the IEP with interventions (IEP 22). It appears that through the introduction of the interventions, there is remaining capacity at the ED. Because of this remaining capacity, the increased number of patients that is send to the ED can be treated without affecting the average LOS significantly. The scenario with IEP 22 will therefore, also by changing the percentages, be considered as better than IEP 3. Furthermore, we see that for every level of the sensitivity analysis, the LOS at the ED of IEP 22 is better than the LOS at the ED compared to NIP 2 and to NIP 44. So, for the ED, IEP 22 is the best scenario for every level of the sensitivity analysis.

Changing the percentage of orange patients that are referred to the ED, has no significant effect on the average LOS at the GP post for both IEP 3 and IEP 22. So, the final outcome remains the same. By changing the percentage of yellow and green patients that are referred to the ED, the average LOS at the GP post does increase significantly. However, in both cases, the average LOS at the GP post remains (far) below the average LOS in IEP 3. The scenario with IEP 22 will therefore, also by changing the percentages, be considered as better than IEP 3.

When we compare the average LOS at the GP post of IEP 22 to the average LOS at the GP post of NIP 2 and of NIP 44, we see that IEP 22 is better than NIP 2, but not better than NIP 44. This is a logical result, because in NIP 44 there are less patient to treat than in IEP 22. When these patients are treated by the same number of staff, this will indeed lead to a lower LOS in the scenario with less patients. However, NIP 44 will not lead to a solution of the high number of self-referrals at the ED (see Section 1.3). Therefore, we prefer IEP 22 (the second best with regard to the average LOS at the GP post) at every level of the sensitivity analysis, because IEP 22 does lead to a solution of the high number of self-referrals at the ED. And as said, this scenario already shows a significant decrease of the LOS at the GP post compared to the NIP.

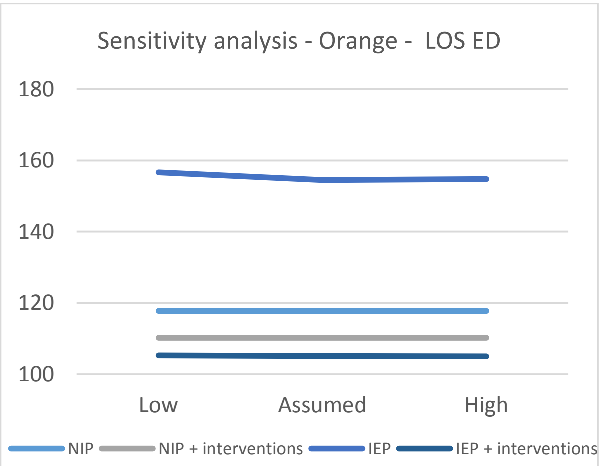


Figure 29
Effects assumption ED urgency orange; LOS ED

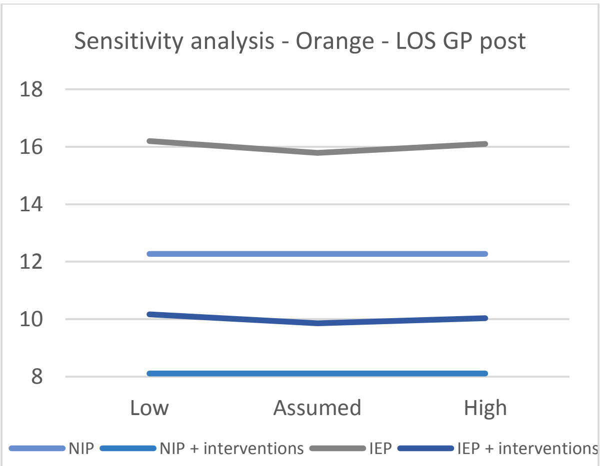


Figure 30
Effects assumption ED urgency orange; LOS GP post

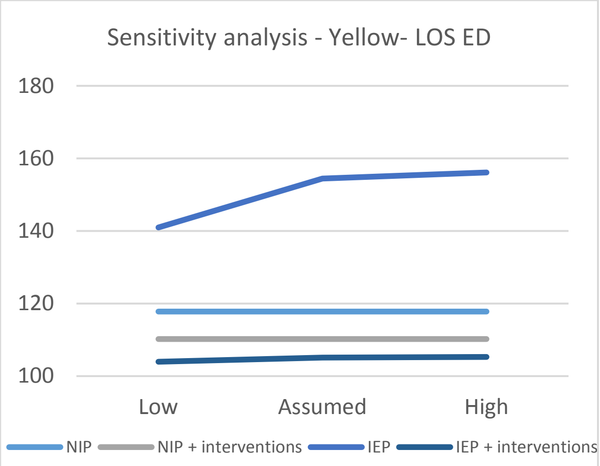


Figure 31
Effects assumption ED urgency yellow; LOS ED

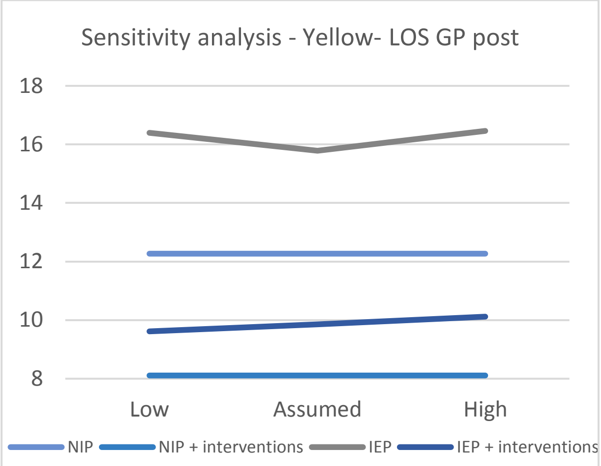


Figure 32
Effects assumption ED urgency yellow; LOS GP post

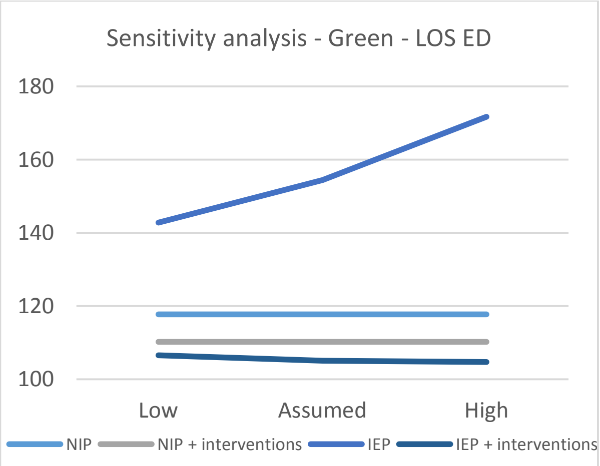


Figure 33
Effects assumption ED urgency green; LOS ED

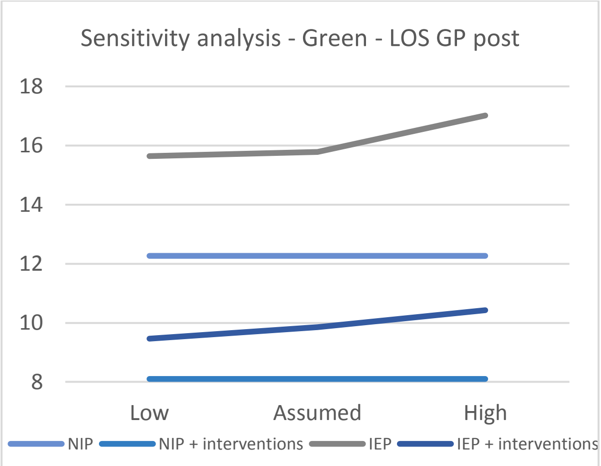


Figure 34
Effects assumption ED urgency green; LOS GP post

6.6 Summary

In this chapter, we used the simulation model to conduct experiments. First, we described the performance indicators that are used in the comparison of different scenarios. Second, we analyzed the effects of integration alone. It appeared that integration alone yields no positive effects on the LOS at the organizations. Therefore, we introduced and analyzed interventions that could contribute to a decrease in the LOS at (one of) the organizations. The interventions that had a significant, positive effect on the LOS at (of one) the organizations, are combined in a 2^k factorial design to identify possible interaction effects. The scenario that is labeled as best combines the interventions of: expanding the ED doctors' authority, adding a NP at the GP post, and using the same triage system. If we compare this scenario to the NIP, it leads to a decrease in the LOS at the ED of 10.77%, and to a decrease in the LOS at the GP post of 19.71%. In a sensitivity analysis, we tested the robustness of this result. From this analysis, we saw that the outcomes hold when changing the percentage of ED self-referrals that is referred to the ED in the integrated situation. Furthermore, we saw that IEP 22 is preferred above NIP 2, IEP 3, and NIP 44.

7 Discussion and conclusion

This chapter starts with a description of the main findings of this research in Section 7.1. In Section 7.2, we describe the discussion, in which we appoint the strengths and limitations of this research. Section 7.2 also describes topics for future research.

7.1 Conclusion

The objective of this research was twofold. First, we wanted to gain insight into the effects of integrating the emergency department of MST and the GP post of Enschede. Second, we wanted to verify the general applicability of an existing discrete-event simulation framework for evaluating integrated emergency posts. To reach this goal, we composed seven sub research questions. All these research questions are addressed in one of the chapters in this thesis (see Figure 1).

In Chapter 2, the first sub question was central, which was: *what is known in literature about simulation, simulation in health care, out-of-hours care, and simulation of out-of-hours care?* We described what simulation is, what the advantages and disadvantages are of simulation, and how a sound simulation study looks like. Furthermore, we saw that simulation is already applied in a variety of fields, and that it offers great potential for health care. This could also be seen from the substantial increase in the number of publications related to simulation in health care. In addition, we have seen that simulation was also previously used in modelling patient flow and resource allocation at emergency departments. Last, we described that some authors already proved the general applicability of a simulation model, and that the use of generic simulation models shows great advantages.

In Chapter 3, we described the process and data analysis. The sub question that was central in this chapter was: *how is the current delivery of out-of-hours care in Enschede organized and how can it be* modeled? The current delivery of out-of-hours care in Enschede can be modeled best as shown in Figure 4. This figure shows how a patient can enter the NIP, how a patient can move through the NIP, and how a patient can leave the NIP. The average number of arrivals entering the NIP at hour *h*, day *d*, and week *w* can be calculated by the formula given in Section 3.2.1. The resources used at the NIP can be divided into rooms, staff, and additional resources (such as diagnostic equipment). The necessity of deployment of these resources and the duration of the deployment of these resources is dependent on the urgency, the path, and the treatment group of the patient.

The second sub question that was central in Chapter 3 was: *what are the changes that occur when the emergency department of MST integrates with the local GP post and how can we model this situation?* The major change when moving to an IEP is that self-referrals can no longer directly go to the ED, but they sign up at one common counter. An IEP can be modeled best as shown in Figure 19. Furthermore, the probabilities of passing a certain A-, B-, or a C-path will change. Also, the probability of receiving a certain GP post urgency at time interval *t*, and the probability of receiving a certain ED treatment group at time interval *t* for GP post referrals will change.

In Chapter 4, the fourth sub question was central, which was: *what changes need to be made in the existing simulation model in order to correctly simulate the organization of out-of-hours care in Enschede?* In order to use the model in Enschede, a number of adjustments had to be made. We distinguished three types of adjustments: generic adjustments, non-generic adjustments, and additions to the model. Eventually, we made thirteen generic adjustments, nine non-generic adjustments, and five additions to the model.

The fifth sub question was central in the beginning of Chapter 6, which was: *on the basis of which performance indicators can the integrated model be compared with the non-integrated model?* The selected key performance indicators for this research are: length of stay at the GP post and length of stay at the ED.

The second sub question that was central in Chapter 6 was: *what are the expected effects when integrating the emergency department of MST with the local GP post?* The results of the simulation model showed that integrating the ED of MST with the local GP post has a significant, negative effect on the LOS at both organizations. The increase in LOS at the GP post was expected, due to the increased number of patients in the integrated situation. The increase in LOS at the ED was unexpected, but it appeared that this is due to the way in which the task are divided among the staff.

In the end of Chapter 6, the last sub question was central, which was: *how can we efficiently organize the integrated emergency post in Enschede and how robust are these effects?* In order to answer this question, we performed experiments which have been set up based on a 2^k factorial design. We saw that expanding the ED doctors' authority, adding a nurse practitioner at the GP post, and using the same triage system together ensure that the changed patient flow can be handled in at least the same manner as in the current situation in terms of waiting time and LOS. If we compare this scenario to the NIP, it leads to a decrease in the LOS at the ED of 10.77%, and to a decrease in the LOS at the GP post of 19.71%.

Main conclusion

Based on the findings of the sub research questions, we can answer the main research question:

"What is the effect of integrating the general practitioners post of Enschede with the emergency department of MST, and in which way can the existing simulation model be used to correctly model the delivery of out-of-hours care in Enschede and to determine the effect of integration?"

Integrating the emergency department of MST with the local GP post (HDT-Oost) yields no positive effects when stakeholders from the organizations are not prepared to implement some organizational changes. However, when the integration is associated with a number of organizational changes, integration will lead to significant, positive effects. The existing simulation model is used in the determination of these effects, after a number of adjustments and additions to the model were made.

7.2 Discussion

In this section, we describe the strengths and the limitations of this research. A number of limitations of the research are starting points for future research. Furthermore, at the end of this section, we describe a number of separate recommendations for future research that not (directly) arise from the limitations of this research.

This research has two major advantages. First, it focused on the effects of integration on the patients, and on the processes that take place the ED and the GP post. By using a computer simulation model, we were able to prospectively determine the effects of integration and to determine how an IEP can be best organized in Enschede. Due to this, this research has a high societal relevance.

Second, we used an existing simulation model and verified the statement of Mes and Bruens (2012) that their model is flexible and general and can easily be adapted to other emergency departments as well as to other departments within a hospital. We adjusted this simulation model, due to which it is now more broadly applicable to other settings. This contributes to the literature, due to which it has a high scientific relevance.

Besides these main advantages, this research has also some limitations. The first relates to the transition from a NIP to an IEP. In this transition, we made some assumptions regarding the GP post urgency the patient gets, the path the patient will go through at the GP post, and the percentage of self-referrals that eventually will end up at the ED. We performed a sensitivity analysis to determine the impact of the last assumption; however no sensitivity analysis is performed with regard to the first two assumptions. We think that it is better to introduce a measurement period, in which a GP triage nurse is present at the triage of ED self-referrals in the NIP. Based on this triage, the GP triage nurse can determine the GP post urgency the patient receives in an IEP, which further steps she would take, and if the patient eventually ends up at the ED. The use of this information as input for the simulation model, will lead to more accurate results.

In this research, we had to make assumptions on the treatment group distribution of one third of the patients, due to the missing entrance complaint (EC) in the data. Despite the fact that we made these assumptions on well-grounded arguments, it is still a rough estimate. It would be beneficial to the accuracy of the model to work with actual data. Therefore, a recommendation for future research is to take a closer look on the patient group without EC.

Furthermore, we made assumptions on the duration of treatment by a resident or a specialist per treatment group. These assumptions were based on estimates from professionals from the field. However, to obtain exact data, a measurement period need to be introduced. Besides, we made assumptions on the need and the amount of diagnostic tests per treatment group. These assumptions are also based on expert opinion, but could be obtained from data. However, these data is not clustered, due to which the analysis of the data takes a lot of time. This did not fit within the time frame of this research, but it will be beneficial to the accuracy of the simulation model to perform this analysis in future research.

The exact length of stay at the GP post cannot be achieved from the data. Although we have good arguments that the current output of the simulation model is valid, it would be advantageous to compare the output from the simulation model with reliable data from practice. Therefore, we suggest to also introduce a measurement period at the GP post, in which we can track the length of stay of patients at the GP post. The advantage of such a measurement period, is that also the waiting times of the patient at the GP post can be registered. As a result, we can also validate the simulation model based on waiting time.

Furthermore, we assumed that the move to the new hospital is only associated with an altered number of rooms. However, it may be possible that the processes are better aligned in the new hospital, due to which the average LOS will change anyway. However, we cannot determine in advance whether there really is such a discrepancy, and if there is, what the size is of this discrepancy.

Future research

For future research, it would be interesting to further optimize the IEP in Enschede. Borgman (2012) already optimized the processes at the IEP in Almelo. However, not all interventions Borgman proposed are applicable to the situation in Enschede. Together with stakeholders from the IEP in Enschede, new interventions can be designed which have potential to optimize the processes at the IEP in Enschede.

In this research, we verified the statement of Mes & Bruens (2012), that the existing simulation model can be adapted to other emergency departments as well as to other departments within a hospital. We have focused on the use of the simulation model in another emergency department. The adjustments and modifications made to the existing simulation model are designed as generic as possible. It would be interesting to reiterate this research in another setting and to see whether if other adjustments and more additions need to be made to the model.

Furthermore, it would be interesting to verify the second part of the statement of Mes and Bruens (2007), which states that the simulation model can be easily adapted to other departments within a hospital. We expect that through application of the simulation model new insights emerge that can contribute to the accuracy of the simulation model.

In this research, we only include performance indicators regarding the LOS of patients at the GP post and LOS at the ED. In our choice of the best experiment, we tried to keep in mind other factors (costs, for example), but this is not based on some kind of (scientific) data. It would be interesting to perform a cost-benefit analysis, to determine what the benefits are of the interventions compared to the costs.

References

Abo-Hamad, W., & Arisha, A. (2013). Simulation-based framework to improve patient experience in an emergency department. *European Journal of Operational Research*(224), 154-166.

Banks, J., & Carson, J. (1988). Applying the simulation process. *Proceedings of the 1988 Winter Simulation Conference*, 52-55.

Borgman, N. J. (2012). *Organizing acute care.* Enschede: Universiteit Twente.

Brailsford, S., Harper, P., Patel, B., & Pitt, M. (2009). An analysis of the academic literature on simulation and modelling in health care. *Journal of Simulation, 3*, 130-140.

Chun, A. H., Chan, S. H., Lam, G. P., Tsang, F. M., Wong, J., & Yeung, D. W. (2000). Nurse rostering at the hospital authority of Hong Kong. *Proceedings.*

Eldabi, T., & Paul, R. (2001). A proposed approach for modeling healthcare systems for understanding. *Proceedings of the 2001 Winter Simulation Conference*.

Facchin, P., Rizzato, E., & Romanin-Jacur, G. (2010). Emergency department generalized flexible simulation model. *Proceedings of the IEEE Workshop on Health Care Management*, (pp. 1-6). Piscataway, New Jersey.

Ferrin, D., Miller, M., & McBroom, D. (2007). Maximizing hospital finanacial impact and emergency department throughput with simulation. *Proceedings of the 2007 Winter Simulation.* New Jersey.

Fletcher, A., Halsall, D., Huxham, S., & Worthington, D. (2007). The DH accident and emergency department model: a national generic model used locally. *Journal of the Operational Research Society, 58*, 1554-1562.

Fone, D., Hollingshurst, S., Temple, M., Round, A., Lester, N., Weightman, A., . . . Palmer, S. (2003). Systematic review of the use and value of computer simulation modelling in population health and health care delivery. *Journal of Public Health Medicine, 25*(4), 325-335.

Fransman, C. T., Hans, E., Snel, J., Verheij, H., & Doggen, C. (2011). *Patient and community preferences for out-of-hours emergency care using best-worst scaling.* Master thesis, University of Twente, Enschede.

Fry, M. (2009). Barriers and facilitators for succesful after hours care model implementation: reducing ED utilisation. *Australasian Emergency Nursing Journal, 12*, 134-144.

Garcia, M., Centeno, M., Rivera, C., & DeCario, N. (1995). Reducing time in an emergency room via a fast-track. *Proceedings of the 1995 Winter Simulation Conference*, 1048-1053.

Giesbers, S., Smits, M., & Giesen, P. (2011). Zelfverwijzers SEH jagen zorgkosten op . *Medisch contact, 66*(10), 587-590.

Giesen, P. (2007). Tussen droom en daad. *Medisch contact, 62*(15), 653-655.

Giesen, P., Franssen, E., Mokkink, H., Bosch, v. d., Vugt, v. A., & Grol, R. (2006). Patients either contacting a general practice cooperative or accident and emergency department out of hours: a comparison. *Emergency Medicine Journal, 23*, 731-734.

Grol, R., Giesen, P., & Uden, v. C. (2006). After-Hours care in the United Kingdom, Denmark and the Netherlands: new models. *Health affairs, 26*(6), 1733-1737.

Gunal, M., & Pidd, M. (2010). Discrete event simulation for performance modelling in health care: a review of the literature. *Journal of Simulation*(4), 42-51.

Hay, A. M., Valentin, E. C., & Bijlsma, R. (2006). Modeling emergency care in hospitals: a paradox - the patient should not drive the process. *Proceedings of the 2006 winter simulation conference*, (pp. 439-445). Monterey.

HDT-Oost. (2012). *Jaarverslagen.* Retrieved november 28, 2013, from HDT-Oost: http://www.hdt-oost.nl/beveiligd_uploads/jaarverslagen/136982076841734_huisartsenpost_enschede_jaarverslag_2012_voor_website.pdf

HDT-Oost. (2013). *Jaarverslagen.* Retrieved from HDT-Oost: http://www.hdt-oost.nl/beveiligd_uploads/jaarverslagen/1400164144jaarverslag_2013___hdt_oost.pdf

Helm, J., AhmadBeygi, S., & van Oyen, M. (2009). The flexible patient flow simulation framework. *IERC Healthcare Logistics Section Conference Proceedings.*

Huibers, L., Giesen, P., Wensing, M., & Grol, R. (2009). Out-of-hours care in Western countries: assessment of different organizational models. *BMC Health services research, 9*(105).

Jacobson, S., Hall, S., & Swisher, J. (2006). Discrete-event simulation of health care systems. In R. Hall, *Patient flow: reducing delay in healthcare deliviery* (Vol. Chapter 8, pp. 211-252). Los Angeles: Springer.

Jun, J., Jacobson, S., & Swisher, J. (1999). Application of discrete-event simulation in health care clinics: a survey. *Journal of the Operational Research Society, 50*, 109-123.

Klink, A. (2008). *Visie op de eerstelijnszorg: 'Dynamische eerstelijnszorg.* Retrieved 12 16, 2013, from Rijksoverheid: http://www.rijksoverheid.nl/documenten-en-publicaties/kamerstukken/2008/01/25/dynamische-eerstelijnszorg.html

Komashie, A., & Mousavi, A. (2005). Modeling emergency departments using discrete event simulation techniques. *Proceedings of the 2005 Winter Simulation Conference*.

Kool, R., Homberg, D., & Kamphuis, H. (2008). Towards integration of general practitioner posts and accident and emergency departments: a case study of two integrated emergency posts in the Netherlands. *BMC Health Services Research, 8*(225).

Law, A. (2007). *Simulation modeling & analysis* (4th ed.). Mc Graw Hill.

Linde, v. d. (2012, October). *Simulating the effect of an integrated emergency post.* Enschede: Universiteit Twente.

Mes, M., & Bruens, M. (2012). A generalized simulation model of an integrated emergency post. *Proceedings of the 2012 Winter Simulation Conference*.

Mielczarek, B., & Uzialko-Mydlikowska, J. (2012). Application of computer simulation modeling in the health care sector: a survey. *Simulation: transactions of the society for modeling and simulation international, 88*(2), 197-216.

Moll van Charante, E., & Bindels, P. (2008). Huisartsenpost en spoedeisende eerste hulp: wel of niet integreren? *Huisarts & Wetenschap, 51*(5), 215-219.

MST. (2012a). *Ziekenhuis Medisch Spectrum Twente.* Retrieved November 28, 2013, from Onze organisatie: https://www.mst.nl/onzeorganisatie/mst_jaarimpressie_2012.pdf

MST. (2012b). *Ziekenhuis Medisch Spectrum Twente.* Retrieved november 28, 2013, from Onze organisatie: https://www.mst.nl/onzeorganisatie/jaarrekening_mst_2012.pdf

MST. (2013a). *Ziekenhuis Medisch Spectrum Twente.* Retrieved augustus 4, 2014, from Onze organisatie: https://www.mst.nl/onzeorganisatie/mst-jaarimpressie-2013.pdf

MST. (2013b). *Ziekenhuis Medisch Spectrum Twente.* Retrieved augustus 4, 2014, from Onze organisatie: https://www.mst.nl/onzeorganisatie/concept-jaarrekening-2013.pdf

Mustafee, N., Katsaliaki, K., & Taylor, S. J. (2010). Profiling literature in healthcare simulation. *Simulation, 86*(8-9), 543-558. Retrieved from http://sim.sagepub.com/content/86/8-9/543

NVZ. (2013). *Acute zorg, er zit meer aan vast dan u denkt!*

Reinders, G. (2012). *Prestatie-indicatoren bij de spoedpost te Almelo; een stakeholderanalyse.* University of Twente.

Reitsma, M., & Jong, d. J. (2010). Betalen voor SEH schrikt af. *Medisch Contact, 65*(29-30), 1479-1482.

Rossetti, M., Trzcinski, G., & Syverud, S. (1999). Emergency department simulation and determination of optimal attending physician staffing schedules. *Proceedings of the 1999 Winter Simulation Conference*, 1532-1540.

Samaha, S., Armel, W., & Starks, D. (2003). The use of simulation to reduce the length of stay in an emergency department. *Proceedings of the 2003 winter simulation conference*, (pp. 1907-1911). New Orleans.

Schippers, E. (2013). *Documenten en publicaties.* Retrieved 12 01, 2013, from Rijksoverheid: http://www.rijksoverheid.nl/bestanden/documenten-en-publicaties/kamerstukken/2013/06/17/kamerbrief-over-niet-invoeren-eigen-bijdrage-zelfverwijzers-spoedeisende-hulp-seh/kamerbrief-over-niet-invoeren-eigen-bijdrage-zelfverwijzers-spoedeisende-hulp-seh.pdf

Shannon, R. (1998). Introduction to the art and science of simulation. *Introduction to the art and science of simulation*, (pp. 7-14). Washington.

Sinreich, D., & Marmor, Y. (2004). A simple and intuitive simulation tool for analyzing emergency department operations. *Proceedings of the 2004 Winter Simulation Conference*, (pp. 1994-2002). Piscataway, New Jersey.

Thorwarth, M., & Arisha, A. (2009). *Application of discrete-event simulation in health care: a review.* Retrieved January 15, 2014, from Dublin institute of Technology: http://arrow.dit.ie/buschmanrep/3

Uden, C., Ament, A., Voss, G., Wesseling, G., Winkens, R., Schayk, v. O., & Crebolder, H. (2006). Out-of-hours primary care. Implications of organisation on costs. *BMC Familiy Practice, 7*(29).

Uden, v. C., Winkens, R., Wesseling, G., Crebolder, H., & Schayk, v. C. (2003). Use of out of hours services: a comparison between two organisations. *Emergency Medicine Journal*(20), 184-187.

Vermue, N., Giesen, P., & Huibers, L. (2007). *Samenwerking tussen huisartsenposten en spoedeisende hulp: huidige situatie en toekomstplannen van huisartsenposten in Nederland.* Nijmegen: IQ healthcare.

Visser, R. (2011). *Modeling an integrated emergency post.* Master thesis, University of Twente, Enschede.

Wang, J., Li, J., & Tussey, K. (2012). Reducing length of stay in emergency department: a simulation study at a community hospital. (1322, Ed.) *IEEE transaction on systems, man, and cubernetics-part A: systems and humans, 42*(6), 1314.

Zeltyn, S., Marmor, Y. N., Mandelbaum, A., Carmeli, B., Greenshpan, O., Mesika, Y., . . . Basis, F. (2011). Simulation-Based Models of Emergency Departments: Operational, Tactical, and Strategic Staffing. *ACM Transactions on Modeling and Computer Simulation , 21*(4).

ZonMw. (2013). *Optimale logistiek en patiënten voorkeuren in de acute zorgketen; de huisartsenpost en spoedeisende hulp in één geïntegreerde post.* Enschede: ZonMw.

Appendices

Appendix A: Steps in a simulation study

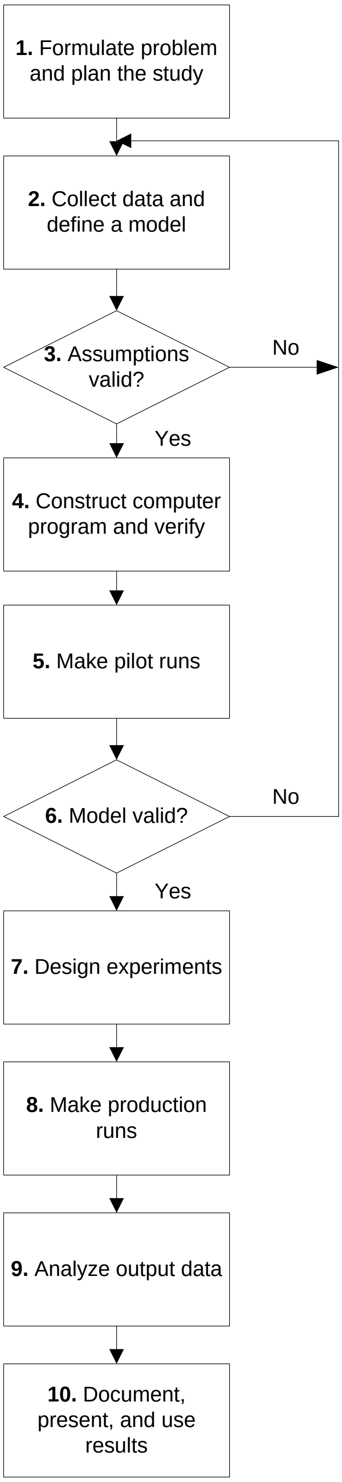


Figure 35
Steps in a sound simulation study (Law, 2007)

Appendix B: Arrivals GP post and ED

Table 43

Average arrivals per day GP post

Hour	Mo-Fr	Sat	Sun	Hour	Mo-Fr	Sat	Sun	Hour	Mo-Fr	Sat	Sun
00				**08**				**16**			
01				**09**				**17**			
02				**10**				**18**			
03		**Confidential**		**11**		**Confidential**		**19**		**Confidential**	
04				**12**				**20**			
05				**13**				**21**			
06				**14**				**22**			
07				**15**				**23**			

Table 44

Outcome Minitab distribution of day factors GP post

	Monday		**Tue-Thu**		**Friday**		**Saturday**		**Sunday**	
	AD	*P*	*AD*	*P*	*AD*	*P*	*AD*	*P*	*AD*	*P*
Normal										
Lognormal										
Exponential					**Confidential**					
Weibull										
Gamma										

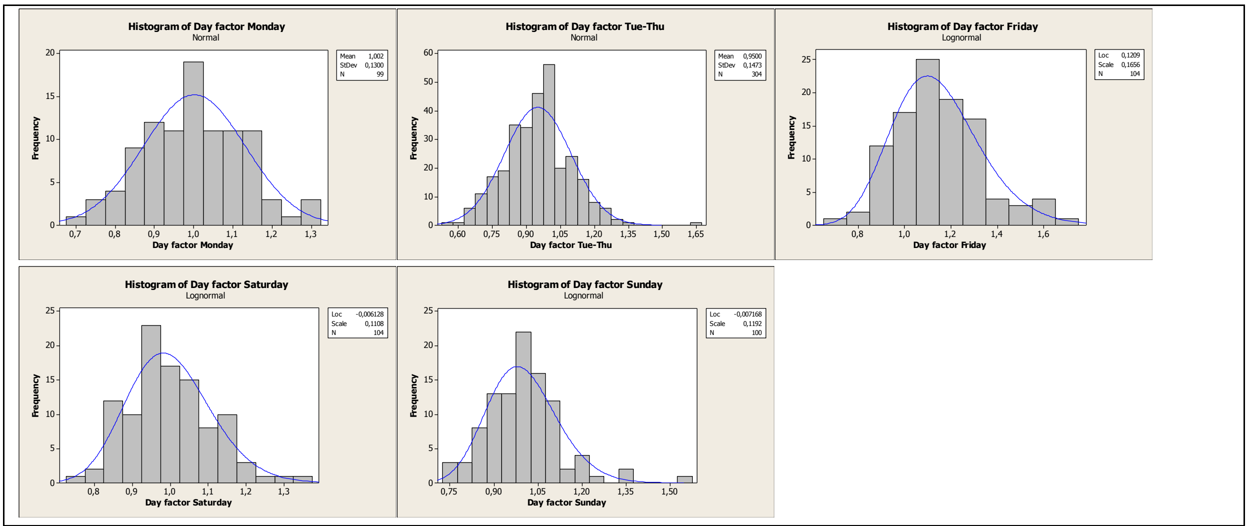


Figure 36

Histogram day factors GP post

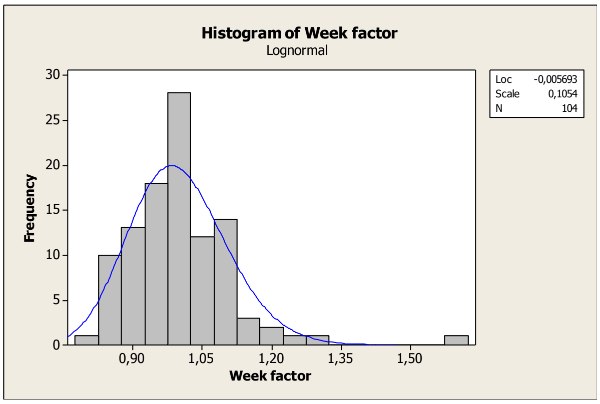


Figure 37
Histogram week factors GP post

Table 45
Outcome Minitab distribution of week factors GP post

	A-D statistic	P-value
Normal		
Lognormal		
Exponential	**Confidential**	
Weibull		
Gamma		

Table 46
Average arrivals per day ED

Hour	Mon-Fri	Sat-Sun	Hour	Mon-Fri	Sat-Sun	Hour	Mon-Fri	Sat-Sun
00			**08**			**16**		
01			**09**			**17**		
02			**10**			**18**		
03	**Confidential**		**11**	**Confidential**		**19**	**Confidential**	
04			**12**			**20**		
05			**13**			**21**		
06			**14**			**22**		
07			**15**			**23**		

Table 47
Outcome Minitab distribution of day factors ED

	Mon & Fri		Tue-Thu		Sat & Sun	
	AD	*P*	*AD*	*P*	*AD*	*P*
Normal						
Lognormal						
Exponential			**Confidential**			
Weibull						
Gamma						

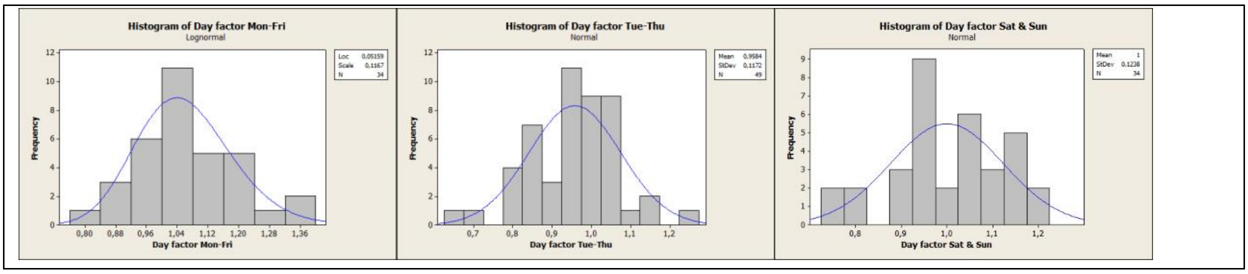


Figure 38

Histograms day factors ED

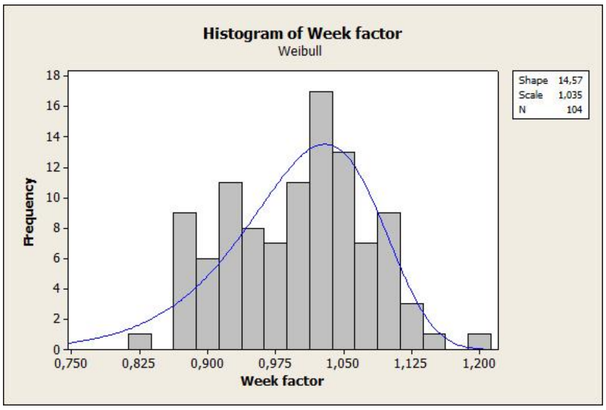


Figure 39

Histogram week factors ED

Table 48

Outcome Minitab distribution of week factors ED

	A-D statistic	P-value
Normal		
Lognormal		
Exponential		**Confidential**
Weibull		
Gamma		

Appendix C: Urgency per time interval

Table 49
GP post urgency per day

Hour	U1	U2	U3	U4	U5
1					
2					
3					
4			Confidential		
5					
6					
7					

Table 50
ED urgency per day

Hour	Red	Orange	Yellow	Green	Blue
1					
2					
3					
4			Confidential		
5					
6					
7					

Table 51
GP post urgency per arrival hour

Hour	U1	U2	U3	U4	U5
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11			Confidential		
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

Table 52
ED urgency per arrival hour

Hour	Red	Orange	Yellow	Green	Blue
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11			Confidential		
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

Appendix D: Urgency distribution per arrival type

Table 53

Urgency distribution external arrivals

Hour	Red	Orange	Yellow	Green	Blue
0-3					
4-7					
8-11			Confidential		
12-15					
16-19					
20-23					

Table 54

Urgency distribution self-referrals

Hour	Red	Orange	Yellow	Green	Blue
0-3					
4-7					
8-11			Confidential		
12-15					
16-19					
20-23					

Table 55

Urgency distribution GP post referrals

Hour	Red	Orange	Yellow	Green	Blue
0-3					
4-7					
8-11			Confidential		
12-15					
16-19					
20-23					

Appendix E: Statistical analyses of the missing EC

Chi-Square test ***urgency*** *with vs. without EC*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4087.942	4	.000
N of Valid Cases	52582		

Chi-Square test ***gender*** *with vs. without EC*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	115.009	1	.000
N of Valid Cases	52582		

Chi-Square test ***arrival year*** *with vs. without EC*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	157.159	1	.000
N of Valid Cases	52582		

Chi-Square test ***arrival hour*** *with vs. without EC*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	191.011	23	.000
N of Valid Cases	52582		

Chi-Square test ***arrival day*** *with vs. without EC*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	32.292	26	.000
N of Valid Cases	52582		

Chi-Square test ***age*** *with vs. without EC*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	475.826	108	.000
N of Valid Cases	52582		

Appendix F: Statistical analysis control group versus sample

*Chi-Square test **urgency** without EC control vs. sample*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.554	4	.817
N of Valid Cases	18420		

*Chi-Square test **gender** without EC control vs. sample*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	0.626	1	.429
N of Valid Cases	18420		

*Chi-Square test **arrival year** without EC control vs. sample*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.101	1	.294
N of Valid Cases	18420		

*Chi-Square test **arrival hour** without EC control vs. sample*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	27.997	23	.216
N of Valid Cases	18420		

*Chi-Square test **arrival day** without EC control vs. sample*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.174	6	.118
N of Valid Cases	18420		

*Chi-Square test **age** without EC control vs. sample*

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	84.917	100	.859
N of Valid Cases	16170		

Appendix G: Treatment group per time interval

Table 56

ED treatment group per day

		Arrival day						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Treatment group	**1**							
	2							
	3							
	4							
	5							
	6				**Confidential**			
	7							
	8							
	9							
	10							
	11							
	12							

Table 57

ED treatment group per arrival hour

		Arrival hour					
		0-3	**4-7**	**8-11**	**12-15**	**16-19**	**20-23**
Treatment group	**1**						
	2						
	3						
	4						
	5						
	6			**Confidential**			
	7						
	8						
	9						
	10						
	11						
	12						

Table 58

ED treatment group vs. ED urgency

		ED treatment group											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
ED urgency	**Red**												
	Orange												
	Yellow						**Confidential**						
	Green												
	Blue												

Appendix H: Treatment group distribution per arrival type

Figure 40

Treatment group distribution external arrivals

		Arrival hour					
		0-3	4-7	8-11	12-15	16-19	20-23
Treatment group	**1**						
	2						
	3						
	4						
	5						
	6			**Confidential**			
	7						
	8						
	9						
	10						
	11						
	12						

Figure 41

Treatment group distribution self-referrals

		Arrival hour					
		0-3	4-7	8-11	12-15	16-19	20-23
Treatment group	**1**						
	2						
	3						
	4						
	5						
	6			**Confidential**			
	7						
	8						
	9						
	10						
	11						
	12						

Figure 42

Treatment group distribution GP post referrals

		Arrival hour					
		0-3	4-7	8-11	12-15	16-19	20-23
Treatment group	**1**						
	2						
	3						
	4						
	5						
	6			**Confidential**			
	7						
	8						
	9						
	10						
	11						
	12						

Appendix I: Patient group vs. path

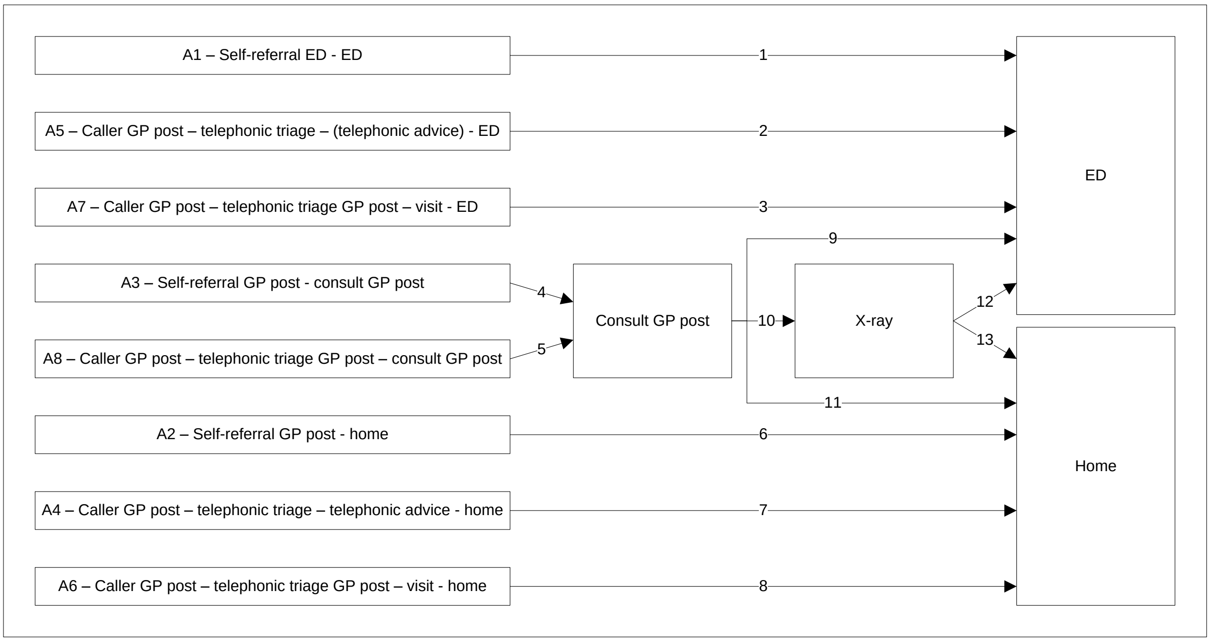


Figure 43
Calculation paths

Table 59
GP post urgency vs. path A

	U1	U2	U3	U4	U5
A1					
A2					
A3					
A4			**Confidential**		
A5					
A6					
A7					
A8					

Table 60
Ratio path B

Path	Ratio
B1	
B2	**Confidential**
B3	
B4	

Table 61
Urgency vs. path C

	Red	Orange	Yellow	Green	Blue
C1					
C2			**Confidential**		
C3					

Table 62
Treatment group vs. path C

	Treatment group											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
C1												
C2						**Confidential**						
C3												

Appendix J: Treatment group dependencies

Table 63

Probability and amount of diagnostics tests per treatment group

	X-ray		**Lab**		**Ultrasound**		**CT scan**		**ECG**	
	P	*#*	*P*	*#*	*P*	*#*	*P*	*#*	*P*	*#*
T1	**Confidential**									
T2										
T3										
T4										
T5										
T6										
T7										
T8										
T9										
T10										
T11										
T12										

P = probability; # = average amount of requested diagnostics tests

Table 64

Urgency vs. chance on specialist

		Chance on specialist	**Waiting time**
Urgency	Red	**Confidential**	
	Orange		
	Yellow		
	Green		
	Blue		

Appendix K: Processing times

Table 65

Processing times stages

<table>
<tr><th>Department</th><th>Task*</th><th>Average duration</th><th>Distribution**</th><th>P1</th><th>P2</th><th>P3</th></tr>
<tr><td rowspan="5">GP</td><td>Telephonic triage</td><td rowspan="42" colspan="5">Confidential</td></tr>
<tr><td>Physical triage</td></tr>
<tr><td>Visit</td></tr>
<tr><td>Consultation NP</td></tr>
<tr><td>Consultation GP</td></tr>
<tr><td rowspan="37">ED</td><td>Physical triage</td></tr>
<tr><td>Anamnesis ED nurse</td></tr>
<tr><td>Anamnesis PA</td></tr>
<tr><td>Plaster</td></tr>
<tr><td>T1 treatment RES</td></tr>
<tr><td>T1 treatment MS</td></tr>
<tr><td>T2 treatment RES</td></tr>
<tr><td>T2 treatment MS</td></tr>
<tr><td>T3 treatment RES</td></tr>
<tr><td>T3 treatment MS</td></tr>
<tr><td>T4 treatment RES</td></tr>
<tr><td>T4 treatment MS</td></tr>
<tr><td>T5 treatment RES</td></tr>
<tr><td>T5 treatment MS</td></tr>
<tr><td>T6 treatment RES</td></tr>
<tr><td>T6 treatment MS</td></tr>
<tr><td>T7 treatment RES</td></tr>
<tr><td>T7 treatment MS</td></tr>
<tr><td>T8 treatment RES</td></tr>
<tr><td>T8 treatment MS</td></tr>
<tr><td>T9 treatment RES</td></tr>
<tr><td>T9 treatment MS</td></tr>
<tr><td>T10 treatment RES</td></tr>
<tr><td>T10 treatment MS</td></tr>
<tr><td>T11 treatment RES</td></tr>
<tr><td>T11 treatment MS</td></tr>
<tr><td>T12 treatment RES</td></tr>
<tr><td>T12 treatment MS</td></tr>
<tr><td>Lab research</td></tr>
<tr><td>Ultrasound</td></tr>
<tr><td>X-ray</td></tr>
<tr><td>CT scan</td></tr>
<tr><td>ECG</td></tr>
<tr><td>Review lab research</td></tr>
<tr><td>Review ultrasound</td></tr>
<tr><td>Review X-ray</td></tr>
<tr><td>Review CT scan</td></tr>
</table>

*RES = resident; NP = nurse practitioner; MS = medical specialist; GP = general practitioner

***Deterministic: P1 = mean; Normal: P1 = minimal duration; P2 = μ; P3 = σ; Lognormal: P1 = minimal duration; P2 = μ; P3 = σ; Gamma: P1 = minimal duration; P2 = α; P3 = β*

Appendix L: Duration delay tasks

Table 66

Processes with delay tasks

What	Task	Delay task	Average duration	Distribution*	P1	P2	P3
Processes GP post	Visit	Travel time to visit	**Confidential**				
Processes ED	Treatment specialist	Wait for SP red patient					
		Wait for SP orange patient					
		Wait for SP yellow patient					
		Wait for SP green patient					
		Wait for SP blue patient					
	Discharge	Wait for discharge					
	Admission	Wait for admission					
Diagnostics ED	Lab research	Wait for diagnostic employee lab research					
	Ultrasound	Wait for diagnostic employee ultrasound					
	X-ray	Wait for diagnostic employee X-ray					
	CT scan	Wait for diagnostic employee CT scan					
	ECG	Wait for diagnostic employee ECG					

**Deterministic: P1 = mean; Normal: P1 = minimal duration; P2 = μ; P3 = σ; Lognormal: P1 = minimal duration; P2 = μ; P3 = σ*

Appendix M: From NIP to IEP

Table 67

Overview paths GP post and ED - IEP

Group	Path
A1	Self-referral – physical triage – ED
A2	Self-referral – physical triage – Home
A3	Self-referral – physical triage – consult GP post
A4	Caller – telephonic triage – telephonic advice – home
A5	Caller – telephonic triage – (telephonic advice) – ED
A6	Caller – telephonic triage – visit – home
A7	Caller – telephonic triage – visit – ED
A8	Caller – telephonic triage – consult GP post

Group	Path
X	External – ED

Group	Path
B1	Consult GP post – home
B2	Consult GP post – X-ray – home
B3	Consult GP post – X-ray – ED
B4	Consult GP post – ED

Group	Path
C1	ED – triage – consult ED – home
C2	ED – triage – consult ED – transfer
C3	ED – triage – consult ED – admission

Table 68

Path A; IEP

	U1	U2	U3	U4	U5
A1					
A2					
A3					
A4			**Confidential**		
A5					
A6					
A7					
A8					

Table 69

Path B; IEP

Path	Ratio
B1	
B2	**Confidential**
B3	
B4	

Table 70

Path C; IEP

	Red	Orange	Yellow	Green	Blue
C1					
C2			**Confidential**		
C3					

Table 71

GP post urgency per arrival hour; IEP

Hour	U1	U2	U3	U4	U5
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11			Confidential		
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

Table 72

Treatment group distribution GP post referrals; IEP

		Arrival hour					
		0-3	4-7	8-11	12-15	16-19	20-23
Treatment group	1						
	2						
	3						
	4						
	5						
	6			Confidential			
	7						
	8						
	9						
	10						
	11						
	12						

Appendix N: Estimating the amount of patients per path - IEP

Table 73

Assigning GP post paths to self-referrals ED

ED urgency	To ED	Stay at GP post	A1	A2	B1	B2	B3	B4	A3
Red	*a*	*b*	(1/1)**a*	-	-	-	-	-	B1-B4
Orange	*c*	*d*	(2/3)**c*	-	(1/2)**d*	(1/2)**d*	(1/6)**c*	(1/6)**c*	B1-B4
Yellow	*e*	*f*	(1/3)**e*	(1/3)**f*	(1/3)**f*	(1/3)**f*	(1/3)**e*	(1/3)**e*	B1-B4
Green	*g*	*h*	-	(1/3)**h*	(1/3)**h*	(1/3)**h*	(1/2)**g*	(1/2)**g*	B1-B4
Blue	*i*	*j*	-	100%**i*	-	-	-	-	B1-B4

The variables a, b, …, j in Table 73 are calculated by the following formulas:

Table 74

Calculating variables in Table 73

Variable	Formula	Variable	Formula
a	α * amount of red self-referrals	f	ζ * amount of yellow self-referrals
b	β * amount of red self-referrals	g	η * amount of green self-referrals
c	γ * amount of orange self-referrals	h	θ * amount of green self-referrals
d	δ * amount of orange self-referrals	i	ι * amount of blue self-referrals
e	ε * amount of yellow self-referrals	j	κ * amount of blue self-referrals

The variables α, β, …, κ are based on the percentages given in Table 21. In a more generic way, the percentages are as given in Table 75. In this table the variables α, β, …, κ represents percentages with a value between 0% and 100%, with the following constraints:

$\alpha + \beta$ = 100 %

$\gamma + \delta$ = 100 %

$\varepsilon + \zeta$ = 100 %

$\eta + \theta$ = 100 %

$\iota + \kappa$ = 100 %

Table 75

Estimation of the amount of self-referrals to the ED at the IEP

	Urgency				
	Red	Orange	Yellow	Green	Blue
To ED	α	γ	ε	η	ι
Stay at GP post	β	δ	ζ	θ	κ
Total	$\alpha + \beta$	$\gamma + \delta$	$\varepsilon + \zeta$	$\eta + \theta$	$\iota + \kappa$

Appendix O: Adjusted tables

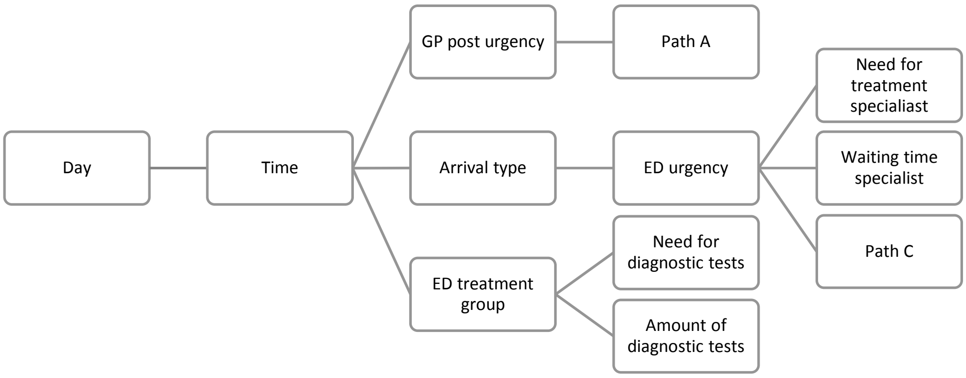


Figure 44
Allocation of patient variables in the existing model

Table 76
ED urgency per treatment group for external arrivals

		ED treatment group											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
ED urgency	**Red**												
	Orange												
	Yellow						**Confidential**						
	Green												
	Blue												

Table 77
ED urgency per treatment group for self-referrals

		ED treatment group											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
ED urgency	**Red**												
	Orange												
	Yellow						**Confidential**						
	Green												
	Blue												

Table 78
ED urgency after GP post urgency; NIP

	U1	U2	U3	U4	U5
Red					
Orange					
Yellow			**Confidential**		
Green					
Blue					

Table 79
ED urgency after GP post urgency; IEP

	U1	U2	U3	U4	U5
Red					
Orange					
Yellow			**Confidential**		
Green					
Blue					

Table 80
Adjusted B-paths

Path B2		
	Existing model	**New model**
1	Consult GP post	Consult GP post
2	X-ray GP post	-
3	Review X-ray GP post	-
4	Consult GP post	-
5	Home	Home

Path B3		
	Existing model	**New model**
1	Consult GP post	Consult GP post
2	X-ray GP post	-
3	Review X-ray GP post	-
4	Travel to ED	Travel to ED
5		

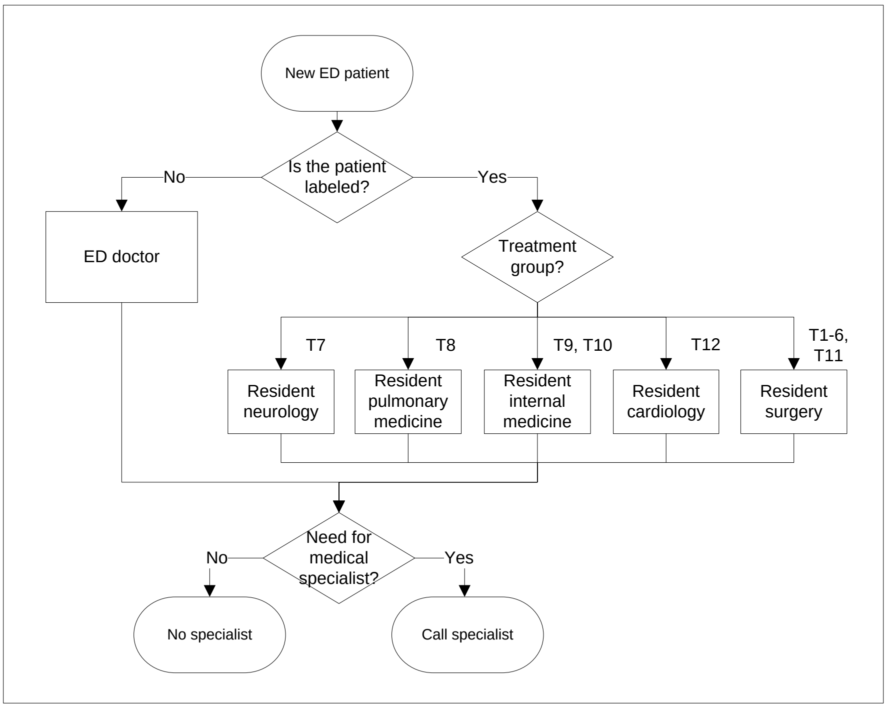


Figure 45
Flowchart "Which staff type ED patients"

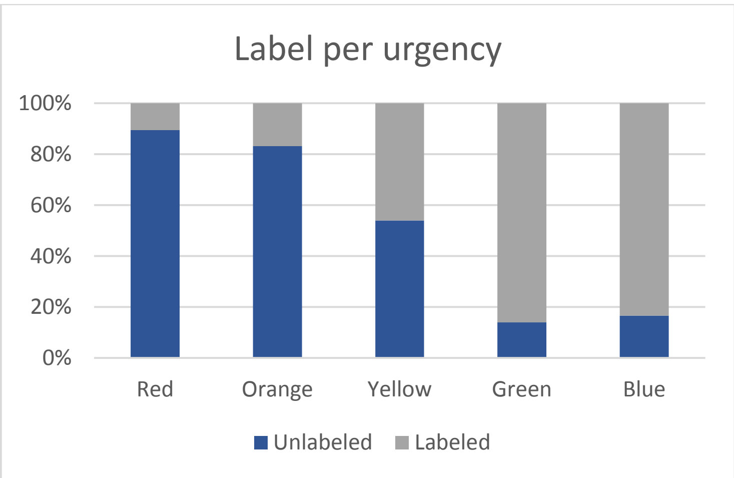


Figure 46
Label per urgency

Table 81

Labeled/unlabeled patients per urgency

	Red	Orange	Yellow	Green	Blue
Unlabeled	**Confidential**				
Labeled					

Table 82

Labeled/unlabeled patients at 17 pm

	Self-referral (23.58%)		**External referral (76.42%)**	
	Unlabeled	*Labeled*	*Unlabeled*	*Labeled*
Chance	**Confidential**		**Confidential**	

Table 83

Allocation GP post urgency and path-A self-referrals ED

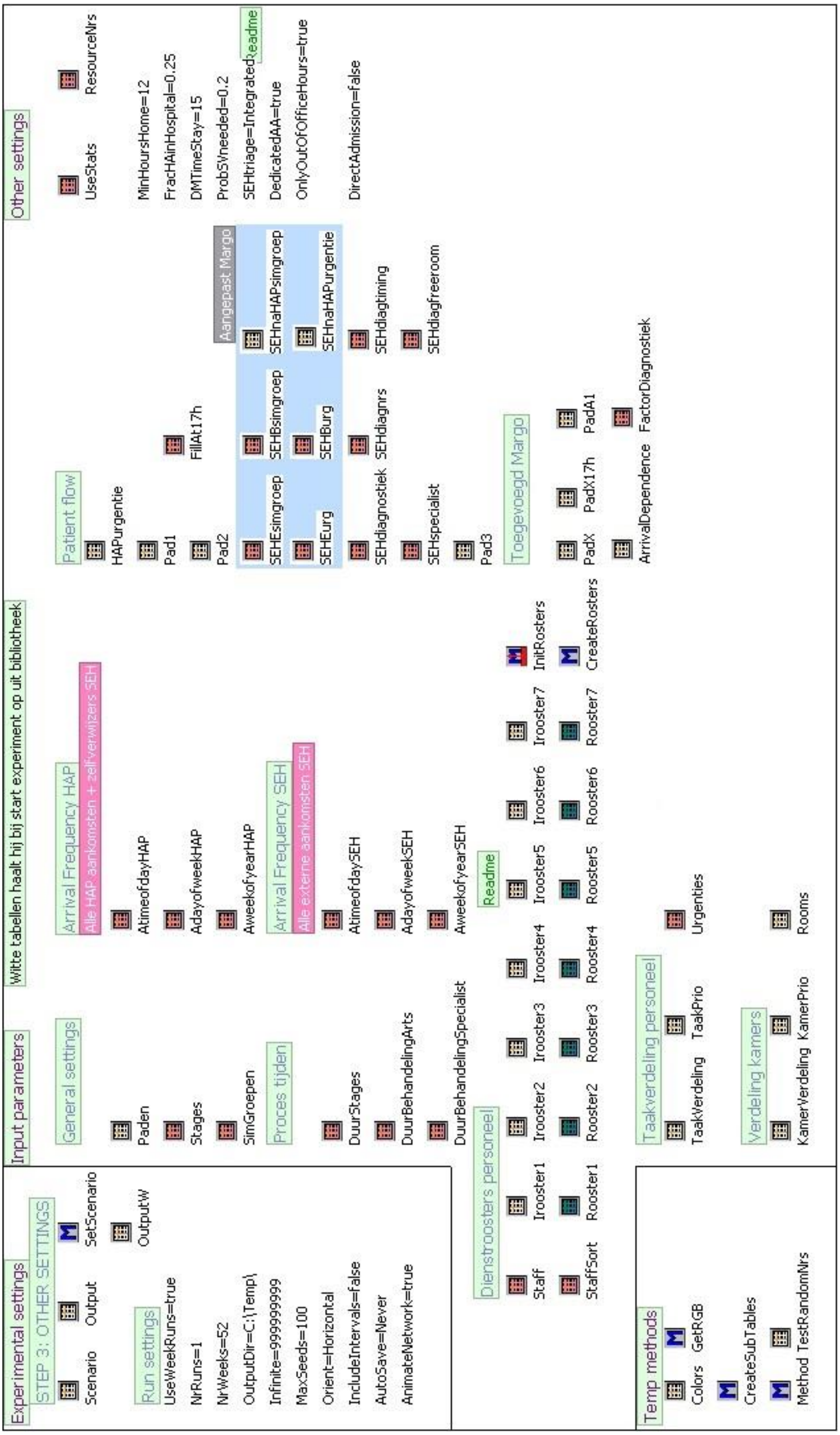
	Chance in NIP	Chance in IEP
Self-referral ED	**Confidential**	
No self-referral ED		

Table 84

Which staff type treats which ED patient

Staff type	Labeled or unlabeled?	Treatment group?
ED doctor	**Confidential**	
Surgical resident		
Neurological resident		
Pulmonary resident		
Internal resident		
Cardiology resident		

Appendix P: Settings frame



Appendix Q: Adjusted arrivals

Table 85

Average non-external arrivals per day

Hour	Mo-Fr	Sat	Sun	Hour	Mo-Fr	Sat	Sun	Hour	Mo-Fr	Sat	Sun
00				**08**				**16**			
01				**09**				**17**			
02				**10**				**18**			
03	**Confidential**			**11**	**Confidential**			**19**	**Confidential**		
04				**12**				**20**			
05				**13**				**21**			
06				**14**				**22**			
07				**15**				**23**			

Table 86

P-values two sample t-test non-external arrivals

	Tuesday	Wednesday	Thursday	Friday
Monday				
Tuesday		**Confidential**		
Wednesday				
Thursday				

* Significant difference

Table 87

Outcome Minitab distribution of day factors non-external arrivals

	Monday		Tue-Thu		Friday		Saturday		Sunday	
	AD	*P*	*AD*	*P*	*AD*	*P*	*AD*	*P*	*AD*	*P*
Normal										
Lognormal										
Exponential					**Confidential**					
Weibull										
Gamma										

Table 88

Underlying distributions day factors non-external arrivals

Day of the week	Distribution	P1	P2
Monday			
Tue-Thu			
Friday		**Confidential**	
Saturday			
Sunday			

Normal: P1 = mean, P2 = standard deviation; Lognormal: P1 = mean, P2 = standard deviation; Gamma: P1 = shape; P2 = scale

The best fitting distribution for the week factors of the non-external arrivals is a gamma distribution with a P-value of 0.436. The corresponding parameters are given in Table 89.

Table 89

Distribution week factors non-external arrivals

Week	Distribution	P1	P2
1-52		**Confidential**	

Lognormal: P1 = mean, P2 = standard deviation

Table 90
Average external arrivals per day

Hour	Mon-Fri	Sat-Sun	Hour	Mon-Fri	Sat-Sun	Hour	Mon-Fri	Sat-Sun
00			**08**			**16**		
01			**09**			**17**		
02			**10**			**18**		
03	**Confidential**		**11**	**Confidential**		**19**	**Confidential**	
04			**12**			**20**		
05			**13**			**21**		
06			**14**			**22**		
07			**15**			**23**		

Table 91
P-value t-test external arrivals

	Tuesday	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Monday						
Tuesday						
Wednesday				**Confidential**		
Thursday						
Saturday						

* Significant difference

Table 92
Outcome Minitab distribution of day factors external arrivals

	Mon & Fri		**Tue-Thu**		**Sat & Sun**	
	AD	*P*	*AD*	*P*	*AD*	*P*
Normal						
Lognormal						
Exponential			**Confidential**			
Weibull						
Gamma						

Table 93
Distribution day factors external arrivals

Day of the week	**Distribution**	**P1**	**P2**
Mon & Fri			
Tue-Thu		**Confidential**	
Sat & Sun			

Normal: P1 = mean, P2 = standard deviation; Lognormal: P1 = mean, P2 = standard deviation

The best fitting distribution for the week factors of the external arrivals is a normal distribution with a P-value of 0.559. The corresponding parameters are given in Table 94.

Table 94
Distribution week factors external arrivals

Week	**Distribution**	**P1**	**P2**
1-52		**Confidential**	

Normal: P1 = mean, P2 = standard deviation

Appendix R: Verification

Table 95

Data vs. model path A; NIP

	Data	Model	Difference
A1			
A2			
A3			
A4		**Confidential**	
A5			
A6			
A7			
A8			

Table 96

Data vs. model GP post urgency; NIP

	Data	Model	Difference
U1			
U2			
U3		**Confidential**	
U4			
U5			

Table 97

Data vs. model path B; NIP

	Data	Model	Difference
B1			
B2		**Confidential**	
B3			
B4			

Table 98

Data vs. model path C; NIP

	Data	Model	Difference
C1		**Confidential**	
C3			

Table 99

Data vs. model treatment group; NIP

	Data	Model	Difference
S1			
S2			
S3			
S4			
S5			
S6		**Confidential**	
S7			
S8			
S9			
S10			
S11			
S12			

Table 100

Data vs. model ED urgency; NIP

	Data	Model	Difference
Red			
Orange			
Yellow		**Confidential**	
Green			
Blue			

Table 101

Data vs. model path A; IEP

	Data	Model	Difference
A1			
A2			
A3			
A4		**Confidential**	
A5			
A6			
A7			
A8			

Table 102

Data vs. model GP post urgency; IEP

	Data	Model	Difference
U1			
U2			
U3		**Confidential**	
U4			
U5			

Table 103
Data vs. model path B; NIP

	Data	Model	Difference
B1		**Confidential**	
B2			
B3			
B4			

Appendix S: Experimental design

Sequential procedure

1) Make n_0 replications of the simulation and set $n = n_0$.
2) Compute $\overline{X}(n)$ and $\delta(n, \alpha) = t_{n-1,1-\frac{\alpha}{2}}\sqrt{S^2(n)/n}$ from $X_1, X_2, \ldots, X_n$.
3) if $\delta(n, \alpha)/|\overline{X}(n)| \leq \gamma'$, use $\overline{X}(n)$ as the point estimate for μ and stop. Else, continue to step 4.
4) Set n := n + 1.
5) Make an additional replication.
6) Go back to step 1.

Operationalization variables formula minimal required number of replications

n^* = minimal required number of replications

$t_{n-1,1-\frac{\alpha}{2}}$ = critical point $t_{v,\gamma}$ for the *t* distribution with *v* df and z_γ for the standard normal distribution

$S^2(n)$ = variance $X_1, X_2, \ldots, X_n$.

$\overline{X}(n)$ = mean $X_1, X_2, \ldots, X_n$.

γ = relative error

Table 104

Duration length of stay GP post integrated minus non-integrated

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12				**Confidential**			
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							

Table 105

Design matrix for the experimental design

Experiment	***ED authority***	***Triage nurse GP post***	***Nurse practitioner***	***General practitioner***	***Same triage***	***Share rooms***	
3)	-	-	-	-	-	-	Response 3
4)	+	-	-	-	-	-	Response 4
5)	-	+	-	-	-	-	Response 5
6)	-	-	+	-	-	-	Response 6
7)	-	-	-	+	-	-	Response 7
8)	-	-	-	-	+	-	Response 8
9)	-	-	-	-	-	+	Response 9

Table 106

Design matrix for the 2^4 factorial design

Experiment	***ED authority***	***Nurse practitioner***	***General practitioner***	***Same triage***	***Response***	***Equal to***
10)	-	-	-	-	Response 10	*= Response 3*
11)	+	-	-	-	Response 11	*= Response 4*
12)	-	+	-	-	Response 12	*= Response 6*
13)	-	-	+	-	Response 13	*= Response 7*
14)	-	-	-	+	Response 14	*= Response 8*
15)	+	+	-	-	Response 15	
16)	+	-	+	-	Response 16	
17)	+	-	-	+	Response 17	
18)	-	+	+	-	Response 18	
19)	-	+	-	+	Response 19	
20)	-	-	+	+	Response 20	
21)	+	+	+	-	Response 21	
22)	+	+	-	+	Response 22	
23)	+	-	+	+	Response 23	
24)	-	+	+	+	Response 24	
25)	+	+	+	+	Response 25	

Table 107

Results 2^k – factorial design

	Emergency department			**GP post**			**Combination of experiment:**
	LOS	*Δ LOS***	*P-value*	*LOS*	*Δ LOS***	*P-value*	
Experiment 10							
Experiment 11							
Experiment 12							
Experiment 13							
Experiment 14							
Experiment 15							
Experiment 16							
Experiment 17				**Confidential**			
Experiment 18							
Experiment 19							
Experiment 20							
Experiment 21							
Experiment 22							
Experiment 23							
Experiment 24							
Experiment 25							