MASTER THESIS

OPTIMIZING THE INTEGRATED EMERGENCY POST IN ENSCHEDE BY THE DEVELOPMENT AND APPLICATION OF A SOLUTION VALIDATION FRAMEWORK

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Management summary

Research motivation

During the last two decennia, the organization of the (out-of-hours) emergency care has radically been changed within the Netherlands. Most patients could decide for themselves to visit the General Practitioner (GP), go directly to the hospital's emergency department (ED) or call the national emergency number. This type of organization resulted into an inefficient way of providing emergency care, which explains the motivation to generate, evaluate and implement alternative emergency care layouts. One of these alternatives is to integrate the GP post and the ED in one organization called the Integrated Emergency Post (IEP). The IEP implementation would force self-referrals to contact the GP post first, which could reduce the workload experienced by the ED. The integration also enables to improve the resource allocations and to reduce the waiting times for both the GP post and the ED. In 2014, a simulation study was conducted to investigate if the IEP implementation would become beneficial for the GP post and ED in Enschede (Koster, 2014). The IEP implementation was realized in the city's new hospital and became operational since the 11th of January 2016. Nowadays, two years of patient records and process data are gathered concerning the actual IEP performances.

Research objectives

The availability of new data provides new research opportunities. First it possible to quantify and visualize the actual IEP performances. Second, the performances can be compared with the initial recommendations made by Koster (2014) to validate the implemented solutions resulting from the discrete-event simulation model developed by Mes & Bruens (2012). Finally the new insights can be used to define new experiments aiming to improve the IEP's efficiency. A clear overview of the benefits and disadvantages of the IEP implementation would allow the stakeholders to make fully informed decisions regarding the organization's layout, processes and resources.

Central research question: How can the out-of-hours care within the IEP Enschede be improved by validating the solutions obtained from a general discrete-event simulation framework?

Research method

No standardized analytical framework exists in scientific literature to execute the solution validation. Most validation frameworks do indicate the importance of solution validation, this final activity is required to compare the expected and actual performances of the recommendations made, allowing the investigators to adapt the implementations made over time. However, all these frameworks assume that the implemented configurations form the only variable that has changed, while the input variables and process descriptions are assumed to remain unchanged, which seems unlikely because more system characteristics can change over time. Therefore, the proposed solution validation framework in Figure 1 does not include the simple comparison between one recommended configuration and one real world description only, but a lot of alternative comparisons between the data sets, model descriptions and configurations simulated are included.

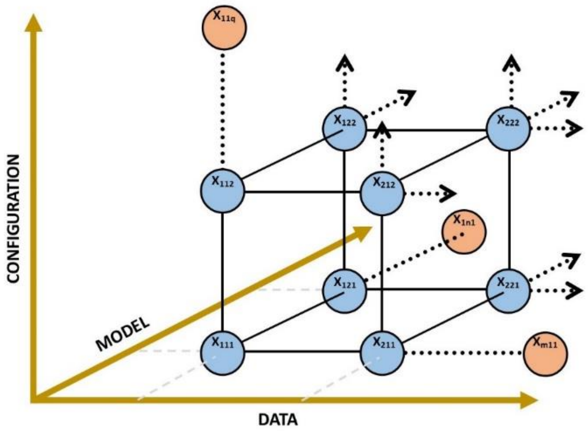

Figure 1: Solution validation framework used for the verification and validation activities included in Robinson's simulation methodology. Each node represents an alternative comparison between data, model and configurations simulated. The total number of comparisons of data sets mϵM, models nϵN and configurations qϵQ is equal to m x n x q alternatives.

Solution validation results

Both the actual GP post LOS and the ED LOS increased over the years. The increases are partly explained by the decision to integrate the GP post and the ED, but the changes are also affected by the changing values of the input variables taken into consideration. Especially the type and number of patient arrivals changed significantly over the years. The simulation model developed by Koster (2014) does not govern all the required elements in order to simulate the separated (2014-2015) and integrated (2016-2017) emergency organization properly. The conceptual model should be expended in order to gain reliable simulation results. The solution validation enables the stakeholders to understand how their operations actually work. The necessity to validate the simulation results makes it possible to see which new configurations have been implemented over time. Comparing the expected and actual IEP performances enables the decision makers to alter their future plans. The solution validation also revealed both past and current bottlenecks within the processes, allowing to construct new experiments. As a result, more insights are gained into the effects of the IEP implementation and the possibility arises to investigate the improvements of new configurations.

Integration results

The ED benefits more from the integration. The transfer of self-referrals to the GP post allowed the ED staff to decrease their workload by approximately 10% on average for 2016 and 2017, which decreases the average ED LOS by 16% (Table 1). The GP post faces more unexpected patient arrivals, which increases the average GP post LOS. However, the GP post is able to take care of the workload increase more efficient in contrast to the ED, because of the ability to schedule the calling patients.

	Patient records				**Simulation output**			
	Separated (2014-2015)		Integrated (2016-2017)		Separated (2016-2017)		Optimized (2016-2017)	
KPI statistic	*time*	*index*	*time*	*index*	*time*	*index*	*time*	*index*
GP post LOS	28.68	85%	33.77	100%	28.82	85%	24.03	71%
ED LOS	138.15	87%	159.38	100%	178.07	117%	106.57	67%

Table 1: A comparison of the actual and simulated LOS values for both the GP post and the ED.

Simulation optimization results

The GP post LOS can be reduced by a maximum of 9:39 minutes (-29%). Larger time slots are preferred in which more patients are invited, while a buffer of waiting patients should be created before a GP can leave the post for patient visits at home. The GP post service level is slightly reduced by 1%, resulting in a final service level of approximately 96%. The service level can be increased by including smaller appointment slots and dispatching GPs for patient visits as soon as possible. It is recommended to create new rosters by removing one GP from the night shift to free staff capacity and add one GP to the evening shift from 5:00pm to 0:00am every day. The ED LOS can be reduced by a maximum of 52:38 minutes (-33%) by implementing new staff rosters for the emergency physicians and surgery/orthopedic residents. Other recommendations are also required, like an increased availability of medical specialists, direct hospital admission and the execution of physical triage activities in the ED treatment rooms. The ED service level is not significantly affected by the new rosters implemented.

Conclusions

The main problem is the lack of insights into the results of the IEP implementation in Enschede since the 11th of January 2016. This problem is solved by customizing the solution validation framework developed in this research. The comparison of all data modifications, model adjustments and alternative configurations make it possible to identify the factors that influenced the actual IEP performances the most. The solution validation also revealed both past and current bottlenecks within the processes, allowing to construct new experiments. The GP post LOS and ED LOS can be reduced by 9:39 minutes (-29%) and 52:38 minutes (-33%) respectively.

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Chapter 1 – Research introduction

1.1. Background information

During the last two decennia, the organization of the out-of-hours care has changed radically within the Netherlands. The out-of-hours care includes all care delivered from 5pm to 8am on workdays, the full weekend and on national holidays (Grol, Giesen & Uden, 2006). Once a patient requires immediate care within this time domain, the out-of-hours care could be provided by two type of organizations: 1) the general practitioners (GP) and 2) the hospitals' emergency departments (ED). The GPs are responsible for the delivery of primary care and should therefore operate as gatekeeper to the access of secondary care, preventing the patients from immediately accessing EDs.

Originally, the primary out-of-hours care used to be organised in small groups in which the GPs joined a rota system (Grol, Giesen, & Uden, 2006) (Uden, et al., 2006). Patients could decide for themselves to visit the GP, go the hospital's ED directly or call the national emergency number (Koster, 2014). This type of organization resulted into an inefficient way of providing emergency care. An increasing number of self-referrals directly went to the hospitals' EDs, while a substantial number of these patients exhibit minor injuries that could be treated by the primary care providers (Uden, Winkens, Wesseling, Crebolder, & Schayck, 2003). This resulted in undesired patient behaviour and an inefficient provision of care, which explains the motivation to generate, evaluate and implement alternative out-of-hours care layouts.

Organizational changes have been introduced in multiple Dutch cities to reduce the ED's number of self-referrals and to provide more efficient out-of-hours care. First, large-scale GPs cooperatives have been set up (Grol, Giesen, & Uden, 2006) (Uden, et al., 2006). Second, a lot of GP started to collaborate with a nearby hospital's ED, which is known as the integrated emergency post (IEP). Both the separated and integrated out-of-hours care are visualized in Figure 2. Note that different IEP organizations exists, the IEP visualization within Figure 2 is greatly simplified.

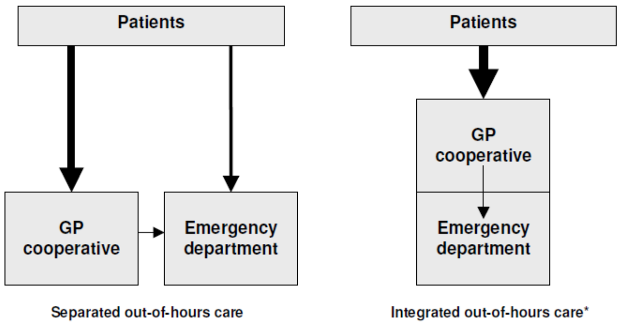


*Figure 2: Simplified comparison between the separated and integrated organization of out-of-hours care (Uden et al., 2006). *Patients with referral or brought in by ambulance go directly to the ED.*

The IEP consists of a large scale GP post and hospital's ED at the same site. An important result of the IEP is the possible reduction in waiting and consultation times (kool, Homberg, & Kamphuis, 2008), which can increase patient satisfaction levels. Giesen (2007) provides another list of benefits that could result from this new type of collaboration: 1) a shift from secondary to primary care, reducing long waiting times and the need for expensive care; 2) a more efficient deployment of people and resources; 3) increased employee satisfaction levels; 4) an increased continuity of care through better coordination between health care providers and 5) a higher patient satisfaction. However, it should be mentioned that both authors refer to the expected benefits, the actual benefits resulting from an IEP organization are hardly addressed within scientific literature.

1.2. Project initiators

Within the Dutch city of Enschede, the (out-of-hours) emergency care has originally been organized by two organizations separately: 1) the GP post of "Huisartsendienst Twente Oost" (HDT) and 2) the ED of "Medisch Spectrum Twente" (MST). The hospital's ED also faced an increasing number of non-urgent self-referrals, which made the two organizations think about the possibility to integrate the GP post and ED into one building. A simulation study has been conducted by Koster (2014) under supervision of "AcuteZorg Euregio", a network organization responsible for the whole emergency care supply chain.

1.3. Research motivation

MST started to build a new hospital in 2012, which created the possibility to integrate the MST's ED and the GP post of HDT. Stakeholders from both organizations expected that the out-of-hours care could be provided more efficiently if the GP post was located directly adjacent to the ED in order to stimulate collaboration between both organizations (Koster, 2014). However, the stakeholders had a lack of insight into the effects of integration on the patients, the processes and performances. Therefore, a simulation study has been conducted in order to investigate the feasibility of an IEP within the new building of MST (Koster, 2014).

In order to quantify the possible effects of integration, Koster (2014) applied a general and flexible discrete-event simulation model that could be adapted to other hospitals' EDs easily (Mes & Bruens, 2012). Within Koster's research, two main objectives were constructed:

1. To gain insight into the effects of integrating the ED and GP post located in Enschede;
2. To verify the general applicability of an existing discrete-event simulation framework for evaluating IEPs.

Koster (2014) concluded that integration of the GP post and ED alone yields no positive effects. On average, the patients' length of stay would increase with 3.52 minutes (+28.62%) for the GP post and 36.73 minutes (+31.20%) within the ED. However, if the integration is associated with some organizational changes, the average length of stay could be reduced with 2.42 minutes (-19.71%) and 12.69 minutes (-10.77%) for the GP post and ED respectively. The best results are obtained if: 1) the ED doctors' authority is expanded; 2) one nurse practitioner at the GP post is added and 3) the same triage system is used for the ED and GP post. Based on these results, Koster also concluded that the simulation model developed by Mes & Bruens (2012) is indeed flexible and general.

Currently, the new hospital is completed and in full operation since the 1st of January 2016, which means that the IEP is operational for almost 2 years. It would be useful to investigate the actual performances of the new IEP, based on the new data obtained from this operational phase.

1.4. Problem description

From a scientific perspective, the validation of the implemented IEP solutions is a valid reason for further research. Solution validation is rarely carried out in practice or not reported in scientific literature, even though it is the only true test of the outcome of a simulation study (Robinson, 2004). However, in order to make sure that useful improvements are recommended for the IEP, the problem context should be analysed in more detail first.

1.4.1. Problem identification

In order to find all relevant problems within the IEP Enschede, interviews and guided-tours were organized with both stakeholders from the HDT's GP post and MST's ED. It turned out that both HDT and MST are mainly concerned with the increased workload experienced by their employees, which results into an inefficient delivery of out-of-hours care. This is remarkable, because a negative trend within the number of emergency treatments is observed nationwide (Twillert, 2018). Based on the expected benefits provided by scientific literature and simulation studies (kool, Homberg, & Kamphuis, 2008; Giesen P. , 2007; Koster, 2014), it was expected that integration of the two organizations improved the out-of-hours care, but it remains doubtful if this has been achieved in Enschede. Therefore, further identification of relevant problems is required.

In Appendix A, an extensive assessment of all relevant problems and cause-effect relationships is included, based on the methodology provided by Heerkens & van Winden (2017). It turned out that most problems could be classified into three main categories:

1. The incomplete implementation of organizational changes and integration of the processes;
2. The differences in triage between nurses from the GP post and ED;
3. Insufficient workforce capacities in order to adequately treat all incoming patients.

These issues cause an increased workload experienced by the employees, but also resulted into irregular occupations of the IEP treatment rooms, unclear patient flows and non-urgent patients at the IEP. In conclusion, the problems identified still result into an inefficient care delivery and a quality reduction of the out-of-hours emergency care.

1.4.2. Core problem selection

A problem is only solved by addressing its root causes. Therefore, the root causes within each problem category are summarized within Table 2.

Problem category	Relevant causes
Insufficient workforce & overcrowding	A1. The arrival of self-referrals is hard to predict
	A2. Patient visits consume a lot of the GP's time relatively
	A3. There is no planning flexibility within the ED and other MST departments
	A4. ED staff turnover is relatively high
	A5. Strict budget constraints for human resources
Incomplete organizational change & integration	B1. The cultural differences between ED and GP post obstruct full integration
	B2. Resistance against organizational changes by experienced personnel
	B3. The facility's layout does not meet the GP post's and ED's requirements for full integration
	B4. Limited quality of information shared between GP post and ED
	B5. No insight into the effects of integration
Different triage	C1. ED triage nurses have too little authority to decide the patient's care path within the GP
	C2. NTS urgency classification is not that useful for ED triage

Table 2: Root causes available for problem solving within each problem category.

Problem B5 seems to be the most interesting problem to solve. Both the GP post and ED stakeholders cannot explain the differences between their expectations and the actual IEP's performances. In order to make sure the problems are correctly addressed, the stakeholders should gain insight into the actual effects of the integration first. Simply increasing the staff's capacity without complete understanding of the resulting operational impacts for example, would not solve the problem's causes, the same problems would simply return in the short term. Once the stakeholders have full insight into the integration effects, a roadmap is provided to solve the remaining root causes given in *Table 2*.

1.4.3. Action problem formulation

In order to make sure that the selected core problem is interpreted correctly by all stakeholders, the core problem is formulated as an action problem. An action problem is defined as the discrepancy between the norm and reality, as perceived by the problem owner (Heerkens & Winden, 2017).

The managers from HDT, MST and Acute Zorg Euregio (problem owners), do not know exactly how to quantify the improvements realized by the integration of the hospital's ED and GP post (reality), based on the recommendations from the simulation study conducted by Koster in 2014. However, a clear overview of the benefits and disadvantages of the IEP implementation would allow the stakeholders to make informed decisions regarding the organization's layout, processes and resources (norm), resulting into an effective and efficient delivery of out-of-hours emergency care. Therefore, the action problem is defined as following:

Action problem: Incomplete insights into the actual performances of integrating the GP post and hospital's ED in Enschede obstruct HDT, MST and Acute Zorg Euregio to organize the out-of-hours emergency care both effectively and efficiently.

1.5. Research objectives

Currently, the integrated emergency post in Enschede is fully operational for 2 years. The available patient records and process data result into new research opportunities. First of all, it is now possible to quantify and visualize the actual performances of the ED and GP integration. Secondly, these performances could be compared with the initial recommendations made by Koster (2014) in order to validate the implemented solution of the generic simulation model developed by Mes & Bruens (2012). Finally, the new insights obtained could result in new recommendations aiming to optimize patient satisfaction and organizational efficiencies within the IEP Enschede.

Given the research motivation described in Section 1.3 and the action problem defined in Section 1.4.3, three main goals can be derived for this research.

Research objective 1: To determine the effects of integrating the ED and GP post into one organizational unit responsible for the out-of-hours care.

The first research objective mainly aims to provide additional insights for the IEP's stakeholders. The analysis of new available data about both patient characteristics and process performances makes it possible to validate the solutions recommended by Koster (2014). The validation should allow the users to quantify the actual benefits of an integrated emergency organization.

Research objective 2: To optimize the IEP's performances by applying a discrete-event simulation model, based on new data obtained from the IEP's actual operations.

Once the actual effects of an integrated emergency post are well known, a new simulation study can be applied in order to optimize the organization's configurations. Therefore, the second research objective aims to improve the performances for all IEP stakeholders by changing the organization's layout, processes and/or resource allocations, resulting into increased satisfaction levels for both patients and staff.

Research objective 3: To verify the validity and applicability of a general and flexible discrete-event simulation model for evaluating IEPs, including its resulting solutions and recommendations.

Finally, the third research objective aims to expand the scientific knowledge regarding the application of discrete-event simulation models. Robinson (2004) states that solution validation is the only true test of the simulation study's outcome, but it is rarely applied in practice. Therefore, once the existing simulation model is completely validated and positive results are obtained, the model could be applied for the analysis of other IEPs or hospital departments (Mes & Bruens, 2012).

1.6. Research questions

The main research question driving this study can be defined as following:

Central research question: How can the out-of-hours care within the IEP Enschede be improved by validating the solutions obtained from a general discrete-event simulation framework?

Several sub questions are composed in order to answer the central research question:

1. Which improvements are expected from integrating the GP post and hospital's ED?
    a. Which IEP achievements are expected theoretically?
    b. Which IEP achievements are obtained from real-life in literature?

2. Which analytical framework could be applied in order to validate and simulate the processes of the IEP Enschede?

3. How is the out-of-hours emergency care organized within the separated GP post and ED (2014-2015) and the IEP Enschede (2016-2017)?
    a. Which processes are implemented for both the GP post and hospital's ED?
    b. Which resources are used for both the GP post and hospital's ED?
    c. How does the integrated emergency post's layout look like?

4. How do the processes, patient flows and resource allocations within the IEP Enschede differ between the expectations from 2014 and the actual organization today?

5. Which modifications are required in order to make Koster's simulation model up-to-date to the new conceptual model?

6. How do the performances differ for both the separated and integrated emergency care organization in Enschede from 2012 up to 2017?
    a. What are the actual and simulated performances for both the integrated and separated emergency care, based on the data gathered by Koster (2014) in between 2012 and 2013?
    b. What are the actual and simulated performances of the separated emergency care based on the data gathered in between 2014 and 2015?
    c. What are the actual and simulated performances of the integrated emergency care based on the data gathered in between 2016 and 2017?
    d. What is the impact of input variables that have changed over the years?
    e. What is the impact of the conceptual model that has changed over the years?
    f. What are the performances of the GP post and the ED if both organizations did not decide to collaborate in one organization?

7. Which organizational configurations will optimize the out-of-hours care within the integrated emergency post of Enschede?
    a. Which configuration settings are interesting for experimentation?
    b. How do the experimental factors influence the organization's KPIs?
    c. Which type of configurations will benefit the stakeholders' interests the most?
    d. What is the robustness of the solutions proposed?

1.7. Problem approach

1.7.1. Formulating the approach

Proper planning is required to achieve the research objectives and to answer the research questions. First, a literature study is required to answer research question 1 and 2, which will result into a clear overview of IEP benefits and research models. Second, data mining techniques are required in order to obtain useful insights into the patient records gathered over the past two years, which will help to answer research question 3 and 4. Finally, in order to answer the remaining questions and to quantify the differences between the expected and obtained performances of the out-of-hours care delivered by the GP post and ED integration, simulation validation techniques should be applied. A more detailed problem approach is given within Appendix B.

1.7.2. Overall research methodology

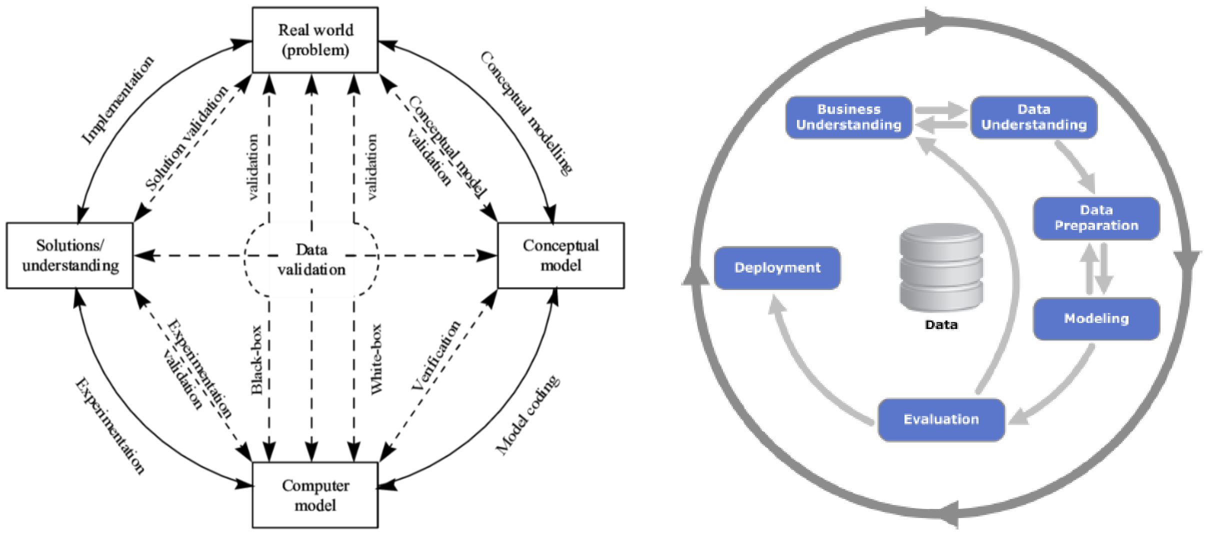
The Managerial Problem Solving Method (MPSM) from Heerkens & van Winden (2017) is an adaptable framework which investigates and solves problems in their organizational context both creatively and systematically. Therefore, the MPSM is applied as research methodology and consists of seven phases: 1) defining the problem; 2) formulating the approach; 3) analyzing the problem; 4) formulating alternative solutions; 5) choosing a solution; 6) implementing the solution and 7) evaluating the solution. The application of the MPSM will ensure that the results are both scientific relevant and useful for business applications.

1.7.3. Simulation & validation methodology

The main aim of this research is to determine the effects of integrating the ED and GP post to improve the out-of-hours care within the IEP Enschede. Since a general and flexible discrete-event simulation model is used for both solution validation and process optimization, a more specific methodology framework should be applied besides of the MPSM. Therefore, the framework developed by Landry et al. (1983) for simulation model verification and validation is applied, which integrates various validation techniques with the key stages and processes within a simulation study (Robinson, 2004). The framework is visualized in Figure 3a.

1.7.4. Data mining methodology

In order to validate the simulation model properly, data records should be analyzed including patient characteristics, resource allocations and the IEP's performances. Therefore, data mining techniques should be applied in order to gain insight into the patient flows and resource utilizations. The Cross Standard Process for Data Mining (CRISP-DM) will be used as data mining methodology, due to the methodology's high utilization in business practice (Tan, Steinbach, & Kumar, 2006). The framework is visualized in Figure 3b.



a) Simulation validation methodology *b) Data mining methodology*

Figure 3: The main methodological frameworks applied within this research. a) The framework developed by Landry et al. (1983) for simulation model verification and validation (Robinson, 2004). b) Visualization of the six-step CRISP-DM process (Tan, Steinbach, & Kumar, 2006).

1.7.5. Report's structure

Within this chapter, the problem identification and problem approach is mainly discussed to elaborate the research's objectives and research questions. A literature study will be performed in Chapter 2, which will result into a clear overview of IEP benefits and research model (research questions 1 and 2). The problem could be analyzed in more detail once the research model is defined, based on the methodological frameworks in Figure 3. First the actual emergency care organization in Enschede is described in Chapter 3 to answer research question 3, the conceptual model will be discussed secondly in Chapter 4 and the required input values are analyzed in Chapter 5 (research question 3 and 4). The simulation model will be explained in Chapter 6, including the modifications required to make the simulation model up to date to today's conceptual model (research question 5). The solution validation itself is discussed in Chapter 7 (research question 6). The results obtained during the solution validation activities will help to construct and evaluate new experiments in Chapter 8 (research question 7). Finally, the conclusions, recommendations and further research will be discussed in Chapter 9.

1.7.6. Research scope

This research main focus is to investigate the effects of integration between the GP post from HDT and the ED from MST by the application of simulation optimization techniques. Therefore, only the processes within the integrated emergency post in Enschede are taken into account. Ingoing and outgoing patient flows are examined, but the patient's care path outside the integrated emergency department is not investigated at all.

Chapter 2 – Literature research & research model

The literature research consists of three main sections. First, the developments in the Dutch emergency care organization will be investigated in more detail. A brief history of the Dutch out-of-hours emergency care developments is already given in Section 1.1., special attention is paid for the recent articles that reveal quantitative results of the IEP implementations. Second, the application of simulation studies itself is examined in more detail. The concept of simulation will be discussed, including some theory about how to conduct a simulation study properly. Examples are given of resulting logistic healthcare improvements. Finally, the application of solution validation in real-life will be investigated.

The literature research will help to develop a suitable research model in order to answer the research questions given in chapter 1. This research model should fit within the solution validation methodological framework proposed by Robinson (2004). The resulting research model will be discussed in Section 2.4. The literature research will help to answer research question 1 and 2:

Research question 1: Which improvements are expected from integrating the GP post and the ED?

Research question 2: Which analytical framework could be applied in order to validate and simulate processes of the IEP Enschede?

2.1. Emergency care developments

The GP posts, EDs and ambulance services are responsible for the out-of-hours emergency care organization in the Netherland (Nederlandse Zorgautoriteit, 2018). Since the first decade of the 21st century, more and more GP posts and EDs started to operate as one integrated organization in order to reduce the number of unnecessary external- and self-referrals at the ED (Nederlandse Zorgautoriteit, 2018) (Grol, Giesen, & Uden, 2006) (Uden, et al., 2006). In 2015, a total of 131 hospitals and 122 GP posts were operational in the Netherlands (Figure 4). Not all hospitals include an ED department, only 95 EDs are operational in the Netherlands, while 71 of these hospitals have a GP post located at the same location (Kommer, Gijsen, Lemmens, & Deuning, 2015).

Multiple objectives were presented in literature by the Vereniging Huisartsenposten Nederland (2010) to implement an IEP organization: 1) The patient satisfaction would increase; 2) The quality of care would increase; 3) Better relationships between the emergency care stakeholders would be obtained; 4) The efficiency would increase and 5) capacity could be allocated more flexible. Facility and personnel sharing between the ED and the GP cooperative may also improve cost-efficiency (Uden et al., 2006). The IEP implementation could also improve the continuity of care through better organization and or improve staff satisfaction levels (Giesen, 2007).

In general, the main objective of the IEP implementation is successfully achieved, less non-urgent self-referrals arrive at the ED (Thijssen, 2016; ZonMw, 2018). Patients that are referred to the ED via the GP post include less waiting time and leave the IEP earlier on average (ZonMw, 2018). Several IEP studies in the Dutch cities of The Hague, Eindhoven, Geldrop and Helmond resulted into positive experiences for both the GP post and ED stakeholders (Bentum, 2010; Paauw, 2017). Half of the ED's self-referrals could be treated by the GP post easily, which reduces the patient's length of stay (LOS) and the treatment's costs. However, most researches include qualitative comparisons only, elaborating the behavioral aspects of patients and staff members only (Bentum, 2010; Coenen, 2012). Therefore, the actual quantitative improvements like waiting time reductions or patient satisfaction improvements resulting from the IEP implementation remain currently unknown.

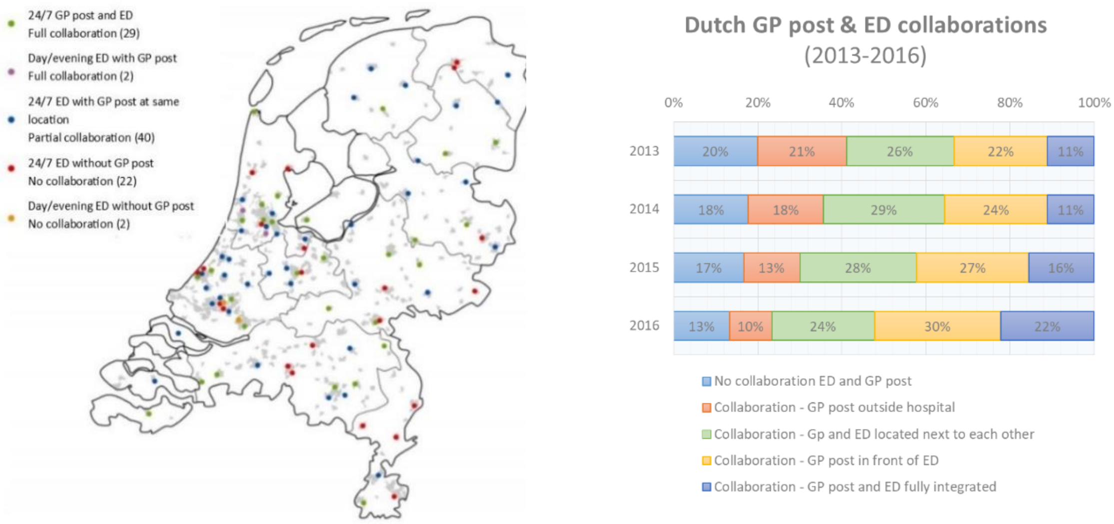


Figure 4: An overview of all the Dutch EDs' and GP posts' locations in 2014 (left), including the type of collaboration between the two organizations (Kommer, Gijsen, Lemmens, & Deuning, 2015). *The number of GP post and ED organizations changes every year (right).*

The question arises if the IEP implementation guarantees sufficient quality of care (Eyck, et al., 2012). Patients require more complex care in comparison with ten years ago, increasing the consult durations and GPs' workload (Visser, 2014; InEen, 2015; ZonMw, 2018). The EDs also experiences overcrowding of their capacities, resulting into reduced productivity, patient- and staff satisfaction levels (Gaakeer, erf, Linden, & Baden, 2018). The logistic performances should be evaluated for several cases in order to determine the actual effects of integrating the GP post and the ED. However, the number of these scientific articles is limited.

The emergency care organization is currently also influenced by changing patient characteristics. The percentage of patients referred from the GP post to the ED increases each year (Thijssen, 2016), because the patients are not distributed across different EDs anymore. Nowadays, patients are referred to the neighboring ED, the IEPs also seem to result into an increase of induced demand.

2.2. Simulation study

2.2.1 What is simulation?

The simplest description of a simulation is that a simulation forms an imitation of a system (Robinson, Simulation: The Practice of Model Development and Use, 2004). A simple version of the real-life system is designed in order to gain insights into the system, to perform experiments or to support communication. Shannon (1975) proposes a detailed simulation definition that can be used in this research.

Citate 2.1 (Shannon, 1975)**:** *Simulation is the process of designing a model of a system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system"*.

Therefore, simulation studies can be used to analyze a system and its performances numerically, while alternative configurations can be modeled for experimentation. Law (2015) also proposes a simulation definition which is more practical.

Citate 2.2 (Law, 2015)**:** *"In simulation, we use a computer to evaluate a model numerically, and data are gathered in order to estimate the desired true characteristics of the model".*

Both Shannon (1975) and Law (2015) state that a simulation represents a simplified representation of a system. The IEP Enschede can be seen as an operational system in order to take care of the emergency patients of the city's surroundings. Law (2015) uses a definition of a system proposed by Schmidt & Taylor (1970) that could be useful to describe the IEP Enschede more abstractly.

Citate 2.3 (Law, 2015): *"A system is defined to be a collection of entities, e.g., people or machines, that act and interact together toward the accomplishment of some logical end"*.

The system's state consists of all the variables required to describe the system itself and its performances at a particular time (Law, 2015). Several alternative methods are available to investigate the system's performances, as visualized by Figure 5.

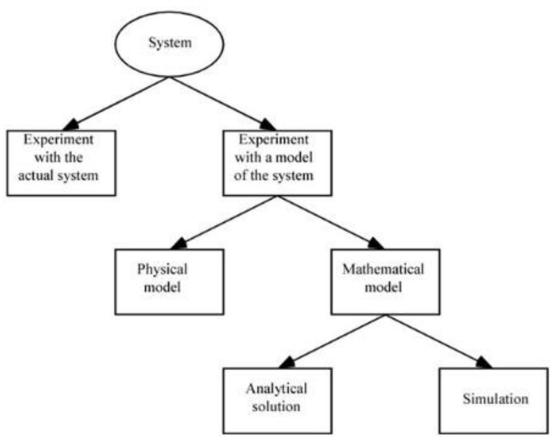


Figure 5: Alternative ways to study a system (Law, 2007).

One could decide to conduct experiments within the system itself, but this may be too costly or too disruptive for the system (Law, 2015). It is even possible that the system does not even exist yet. Therefore, a model of the system is required in order to represent the actual system in a more simplified version. Especially the usage of mathematical models allows the investigator to determine and/or alter the logical and quantitative relationships between the system's entities. Law (2015) states that if the model is relatively simple to solve, it may be possible to get an exact analytical solution by solving the analytical model's equations directly.

There are also systems with a lot of state variables, resulting into a complex mix of relationships affecting on each other. The system may be too complex in order to analyze the system's state analytical. Simulation modeling may form a suitable tool if the system includes a high combinatorial complexity or if high variability is included due to stochastic processes (Law, 2015) (Robinson, Simulation: The Practice of Model Development and Use, 2004).

Simulation modeling offers several advantages for the system's investigator (Law, 2015) (Robinson, Simulation: The Practice of Model Development and Use, 2004). Costly and risky real-life interventions are avoided, the experiments can be created and executed multiple times in a save non-impacting environment. Secondly, long time frames can be simulated in just a few seconds. Thirdly, the experimental factors can be designed freely, the absence of real-life restrictions allows the investigator to investigate some extreme conditions. However, simulation modeling also some disadvantages. Simulation software may be expensive and the activities of data gathering, programming, debugging and experiment analysis may be time consuming. Simulation models also require a lot of data to run properly, which may result into problems if the data is not available. Finally, the simulation model's output may be misleading if the model's assumptions and simplifications are not correctly defined.

2.2.2. Discrete-event simulation

Figure 5 revealed that a simulation model forms a mathematical representation of a system which is useful for experimentation. However, alternative simulation models exists (Law, 2015):

1. **Static versus dynamic simulation models:** if the simulation model represents the system only for a particular point in time, the model is considered to be static. A dynamic system represents the system for an evolving time horizon;
2. **Deterministic versus stochastic simulation models:** if the system includes random variables resulting in variability of the system's outcomes, the model is considered to be stochastic. Otherwise the simulation model is fully deterministic, including known parameters only;
3. **Continuous versus discrete simulation models:** if the system is simulated for an infinite small time interval, the simulation model is considered to be continuous. Otherwise, the system is discrete, which means that particular moments in time are simulated only if an event occurs that changes the system's state.

In this research, a discrete-event simulation model is taken in to consideration. A discrete-event system can only change it state at a countable number of points in time (Law, 2015). The benefit of a discrete-event simulation is that the simulation clock can jump from event to event, because the system's state is only modified once an event occurs.

A discrete-event simulation model consists of several elements, regardless of which software tool is used (Law, 2015). The elements are listed below, while the interrelationship between all elements is visualized in Figure 6:

1. **System state:** the collection of state variables required to describe the system at a particular moment in time;
2. **Simulation clock:** a variable representing the time simulated already;
3. **Event list:** a list of all scheduled events and the time when each type of event will occur;
4. **Statistical counters**: the system's variables used for storing statistical information about the system's performances;
5. **Initialization routine:** a subprogram used to initialize the simulation model at time t=0;
6. **Timing routine:** A subprogram that determines the next event from the event list. The time routine advances the simulation clock to the time at which the next event occurs, the intermediate time interval does not contain any events and is therefore skipped completely;
7. **Event routine:** A subprogram that updates the system's state variables when a particular type of event occurs. Each event includes a separate event routine;
8. **Library routines:** a set of subprograms used for the random generation of observations by using probability distributions;
9. **Report generator:** a subprogram that computes and stores all key results for the statistical counters defined. The report is generated once the simulation ends;
10. **Main program:** a subprogram that invokes all other subprograms. The timing routine is invoked to determine the next event and the event routine takes over the system modifications itself. The main program is also responsible for finishing the simulation and initiating the report generator.

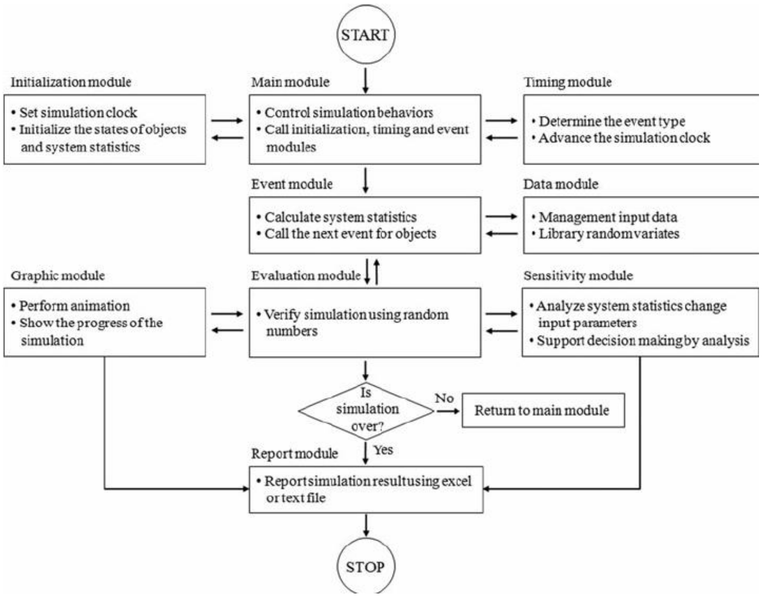


Figure 6: Flow of control for the next-event time-advance approach (Law, 2015).

2.2.3. Simulation process

A wide variety of simulation model frameworks exists in literature (Robinson, Simulation: The Practice of Model Development and Use, 2004). While the processes are named differentially and the number of sub-classifications may be changed, all these model frameworks include the same basic components visualized in Figure 7:

1. **Conceptual model:** a description of the model that is to be developed;
2. **Computer model:** the simulation model programmed into a computer;
3. **Solutions and/or understanding**: the results obtained from experimentations;
4. **Real-world improvements:** the implementation of the best configurations.

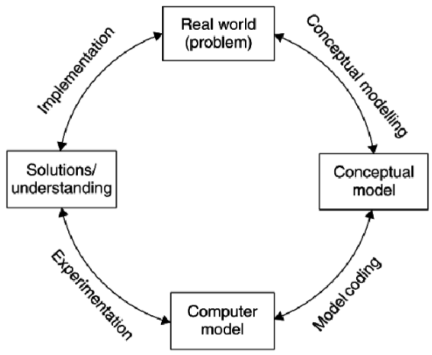


Figure 7: A simulation's key stages and processes (Robinson, 2004).

Law (2015) proposed a more detailed simulation framework based on the work of Banks et al. (2010), which is visualized in Figure 8. The key stages identified by Robinson (2004) are also inserted into the simulation steps of Law.

2.2.4. Healthcare simulation examples

Operation techniques like simulation modelling are often applied in order to improve healthcare services, facilities and logistic performances. Gul & Guneri (2015) provide a comprehensive review of ED simulation applications. Several simulation techniques are applied in healthcare environments like Discrete-event simulations, Monte Carlo simulations, System Dynamics and Agent-Based simulation (Mustafee, Katsaliaki, & Taylor, 2010). A lot of examples can be found in scientific literature, like the assessment of the implementation of a fast-track system for hospital emergency services (Kuo, Leung, Graham, Tsoi, & Meng, 2018), patient flow optimization (Saghafian, Austin, & Traub, 2015) and improving the patient referring process (Chen & Lin, 2017). Simulation techniques can also be used to evaluate alternative healthcare institutions' layout designs, which enables the fields of operations management and heatlth care process design to be integrated in order to gain more efficient health care facilities (Boucherie, Hans, & Hartmann, 2012).

2.3. Verification & validation

2.3.1. The verification & validation concept.

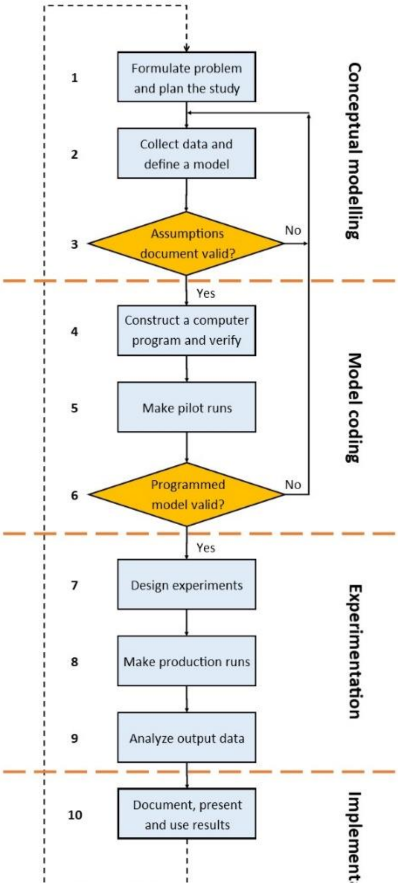


Figure 8: Simulation steps proposed by law (2015), in combination with Robinson's general stages (2004).

Verification is the process of evaluating if the conceptual model is correctly programmed into the simulation model, while validation includes the process of ensuring that the underlying conceptual model is able to represent the simulation's system and objectives adequately (Law, 2015) (Robinson, Simulation: The Practice of Model Development and Use, 2004). The simulation model's experiment results will become reliable once the simulation model is correctly verified and validated.

In Section 1.7.3., the framework developed by Landry et al. (1983) was proposed as main research methodology, which integrates various validation techniques with the key stages and processes within a simulation study (Robinson, Simulation: The Practice of Model Development and Use, 2004). The definitions made by Robinson corresponding to each type of validation is given below:

1. Conceptual model validation: determining if the content, assumptions and simplifications proposed are sufficiently accurate;
2. Data validation: determining if the data required is gathered, processed and applied sufficiently accurate;
3. White-box validation: determining that separated sub-modules of the computer model represent the real-worlds elements with sufficient accuracy;
4. Black-box validation: determining that the overall model represents the real-world with sufficient accuracy;
5. Experimentation validation: determining that the experimental procedures provide sufficiently accurate results;
6. Solution validation: determining whether the results obtained by the simulation model are sufficiently accurate in comparison with the real-world's performances.

2.3.2. Verification and validation in practice

The verification and validation processes should result into a quantified level of agreement between the experimental data and the predictions made by the simulation model with sufficient accuracy (Thacker, et al., 2004). However, the activities of verification and validation are not commonly applied in practice, as stated by Robinson (1999):

Citate 2.4 Robinson (1999): *"Verification and validation is far from straightforward and is often not performed as thoroughly as it might be.*

A large number of verification and validations methodologies is recognized in scientific literature, but no unique validation test exists that can easily be applied to determine the model's correctness (Sargent, 2009). Graphical data comparisons and the usage of confidence intervals will help the validity activities (Kleijnen, 1999), but no standardized format exists in literature so far. Especially the activity of solution validation is rarely carried out in practice, while this is the only true test of the simulation study's outcome (Robinson, 2004). Time issues, data gathering and staff availability form the main reasons why the solution validation is not performed. The simulation model's in industry are also relatively small-scaled, which makes it for the corresponding decision makers not relevant to validate the solutions obtained (Robinson & Brooks, 2010).

2.4. Resulting research model

2.4.1. Research gap

Several research gaps can be identified based on the literature research performed:

1. The absence of quantitative results of the GP post and ED integration;
2. The absence of reported solution validation activities;
3. The absence of a standardized verification and/or validation framework.

First, there are just a few quantitative results of the GP post and the ED integration available in scientific literature. A lot of expectations are published during the first decade of the 21st century, because of the problems caused by the high number of self-referrals at the ED. However, no research evaluates the actual results of the GP post and the ED integration. Only some qualitative comparisons are made for a few locations in the Netherlands, but no real insights are obtained due to missing data.

Secondly, the activity of solution validation is not represented in scientific literature. Most simulation methodologies recommend to finish a simulation study by evaluating the results in comparison with the actual data gathered. Some studies do initiate which activities are required for the solution validation, but the activities itself and their results are not reported in literature research.

Finally, no standardized framework exists yet in order to conduct the solution validation activities consequently. A lot of qualitative and quantitative metrics and tools are available to guarantee that the simulation model is successfully verified and validated. However, no prescriptive model is available in order to conduct the solution validation itself. The number of comparisons made is also too limited, as will be discussed in the next subsection.

2.4.2. Research model

The simulation validation methodology of Robinson (2004) is used in order to identify which models should be compared to each other in order to gain reliable simulation results, while the Law's simulation steps in Figure 8 are applied to structure the research report. However, no clear model is available in order to execute the solution validation properly. Therefore, a new research model is developed for this purpose

Most of the validation frameworks available in scientific literature do indicate the importance of solution validation. This final activity is required to compare the expected and actual performances of the recommendations made, allowing the investigators to adapt the implementations made over time. However, all these frameworks assume that the configurations actually implemented forms the only variable that has changed since the beginning of the simulation study. The input variables and process descriptions are assumed to be unchanged, which seems unlikely because the time passed away.

It can be concluded that more system characteristics can change over time. The conceptual model on which the simulation is based may change over time, including new, adapted or removed processes. The input variables may also change because of new data sets available. Alternative process and data descriptions may become available for different moments in time, because the system develops incrementally. Therefore, solution validation should not include alternative configurations only, as visualized in Figure 9. The proposed research model consists of three main components:

1. **data modifications**: the number of data sets $m \epsilon M$ including different input variable values;
2. **model modifications**: the number of process modifications $n \epsilon N$ in the conceptual model;
3. **Configurations**: the number of experiments $q \epsilon Q$ simulated and eventually recommended.

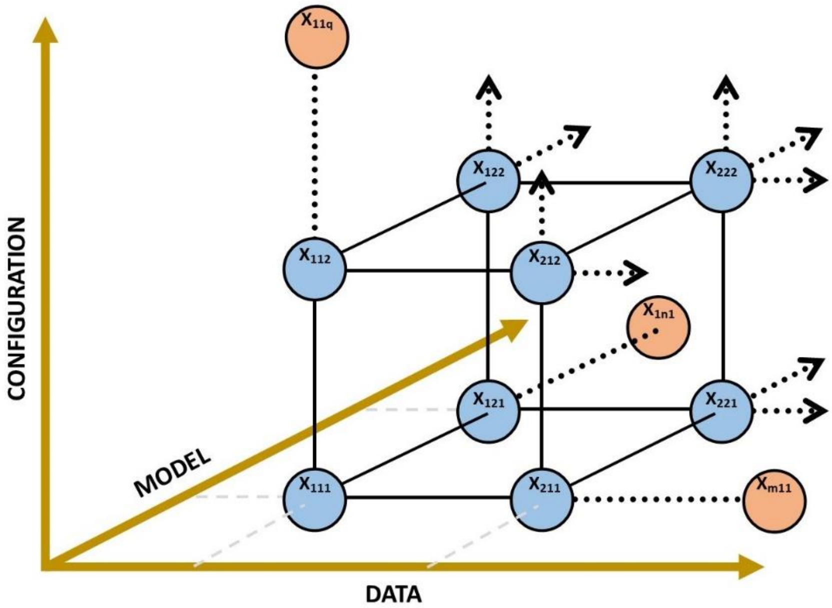


Figure 9: The research model proposed in order to evaluate the verification and validation activities included in Robinson's simulation validation methodology. Each node represents an alternative comparison between data sets, model descriptions and configurations simulated. The total number of comparisons of data sets mϵM, models nϵN and configurations qϵQ is equal to m x n x q alternatives.

The solution validation framework in Figure 9 does not include the simple comparison between one recommended configuration and one real world description only, but a lot of alternative comparisons between the data sets, model descriptions and configurations simulated are included. If X_{mnq} represents the comparison of data set mϵM, model nϵN and configuration qϵQ with each other, a total of m x n x q alternative comparisons could be made in theory. The solution validation does not include an one-dimensional comparison as visualized by Robinson (2004), but a three-dimensional framework consisting of alternative comparisons.

The research model in Figure 9 makes it possible to evaluate and compare the simulation results for all model descriptions and data sets used. The alternative model comparisons are visualized by the blue circles in Figure 9 (some orange cirkels are included to visualize the maximum dimension of each component in the research model). In this way, insights are gained by comparing the impacts of changed processes, input variables and model assumptions.

2.4.3. New contributions to scientific literature

First, this research will be useful for the IEP stakeholders to make their processes more effective and efficient. The results can be used to evaluate the process and input variables that have changed over the years, allowing the IEP stakeholders to make more informed decisions regarding the emergency care organization. New experiments can be performed to improve the IEP's performance once the simulation model and results are fully validated.

Secondly, the research results can be used to fill the research gaps identified in Section 2.5.1. This research provides a wide range of quantitative output variables of the actual IEP performances. Therefore, insights are gained into the actual effects of integrating the GP post and the ED. This research also provides examples of the benefits that could result from executing the solution validation completely. Finally, the research model developed can be used to start a discussion about a standardized validation framework. This new framework should allow the researcher to evaluate all relevant model results to each other.

Chapter 3 – Out-of-hours emergency organization

The IEP organization itself has to be investigated first in order to provide insights into the processes, resources and performances of both the GP post and ED. A conceptual model should be developed that can be used for simulation model's implementation. Therefore, a process analysis will be conducted in this chapter, which will provide an answer to research question 3.

Research question 3: How is the out-of-hours emergency care organized within the separated GP post and ED (2014-2015) and the IEP Enschede (2016-2017)?

The organization of the out-of-hours emergency care is described for two situations: 1) the separated provision of emergency care before integration in 2014-2015 and 2) the emergency care after integration of the GP post and ED in 2016-1017. The two organizational situations are separately described for validation purposes. The required data is obtained from patient records, stakeholder interviews, guided tours and own observations. The investigation includes a review of the processes, resources and layouts of both the ED and GP post within the out-of-hours emergency care organization in Enschede.

3.1. Organizational layout

3.1.1. Layout before integration (2014 & 2015)

Even before the integration of the GP post and ED, both organizations were closely located to each other. Both organizations had their main entrance located near to the main entrance of the MST hospital. The ED was located inside the hospital itself (Figure 10a), while the GP post was located outside of the hospital (Figure 10b). The GP post and ED were located next to each other, but there was no direct connection available between the two organizations. Therefore, patients could simply decide for themselves which organization to visit if they require emergency care.

a) Hospital entrance, including the ED entrance

b) GP post entrance, which is located outside the hospital

Figure 10: Main entrance of the hospital in Enschede between 2014 and 2015. The entrances of both the GP post (HDT-Oost) and ED (MST) were strictly separated, which allowed patients to choose by themselves which organization to visit.

3.1.2. Layout since integration (2016 & 2017)

The new hospital became operational since January 2016, which included the integration of the GP post and the ED into the same department. Emergency patients cannot enter ED via the hospital's main entrance during out-of-office hours anymore (Figure 11a), they have to contact the IEP which is located outside of the hospital (Figure 11b). Both the GP post and ED are accessible via the IEP's main entrance, which excludes the opportunity for patients to choose by themselves where to go.

a) MST hospital main entrance.

b) IEP entrance, including both the GP post and ED.

Figure 11: Since 2016, the IEP's entrance is strictly separated from the hospital's main entrance. The GP post and ED make use of the IEP entrance, which excludes the opportunity for patients to choose by themselves which organization to visit.

Figure 12 visualizes the IEP layout, consisting of the GP post and ED located next to each other. Both organizations share the same main entrance, which includes two rooms reserved for the triage of self-referrals from both the GP post and ED. An additional entrance is used for the arrival and departure of the ED's emergency patients who travel by ambulance. The GP post can refer patients for further treatment to the ED, while the ED can admit patients into the hospital. All other activities or patient flows happen within the GP post or ED separately.

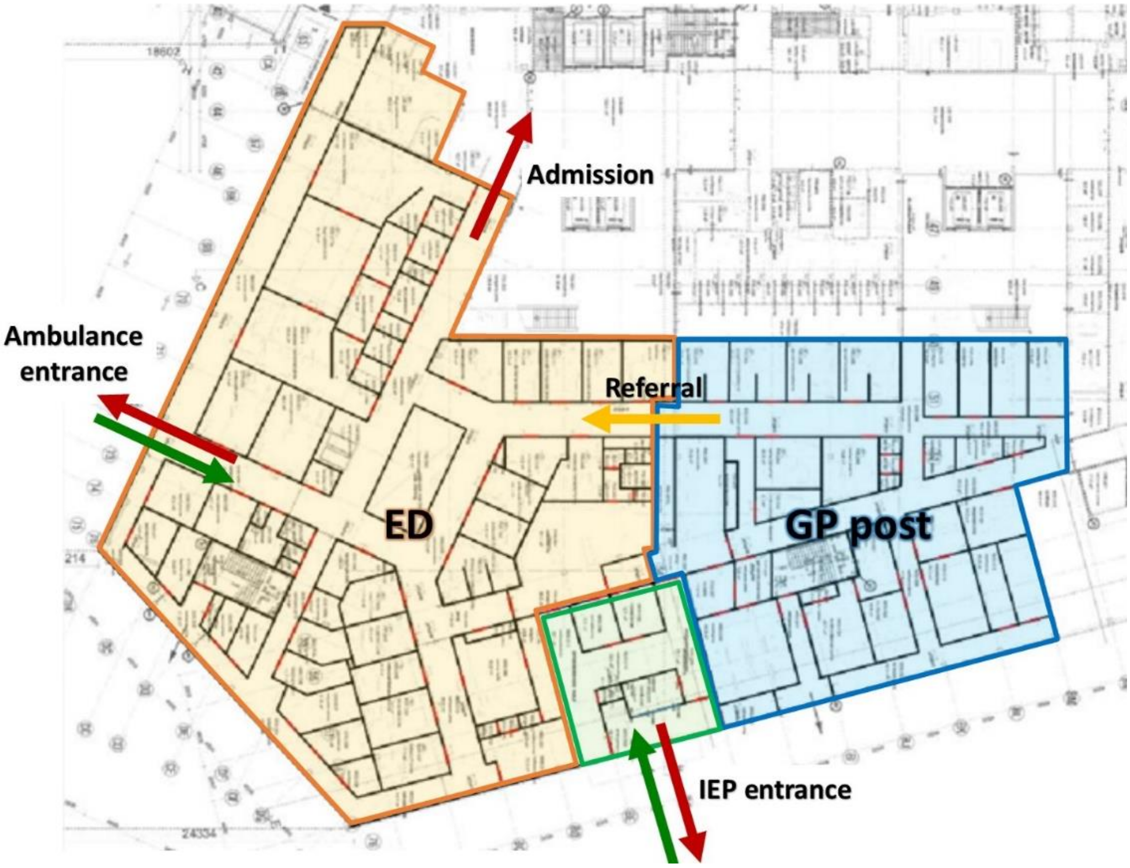


Figure 12: Layout overview of the IEP Enschede, including the GP post (blue) and ED (orange). The green marked area represent the area reserved for physical triage by both organizations. The patient inflows are visualized by green arrows, while patient outflows are marked by red arrows. It is possible for a GP to refer patients for futher treatment to the ED (yellow arrow).

3.2. Patient flows

All patients can enter the IEP Enschede via two different entrances only, represented by the green arrows in Figure 12. Emergency patients transported by ambulance, trauma helicopter or the police will enter the ED directly via the ambulance entrance. All other patients will enter the IEP via the main entrance first for a physical consult. This strict separation of patient flows was not the case for the separated emergency organization between 2014 and 2015. Therefore, the patients' in- and outflows will be discussed in more detail for both the separated and integrated form of emergency care organization. The IEP's layout in Figure 12 will help to visualize the patient flows since 2016.

Please notice that not all treated patients actually visit the IEP physically. Some patients are visited by the GP at home, these patients may stay at home if the complaints are treated adequately or visit the ED. On the other hand, telephonic advice could be provided by the GP and GP assistants, preventing unnecessary usage of the IEP's resources. It is necessary to discuss these different type of patient flows in- and out the IEP separately, because the performance indicators regarding the patients' length of stay should be calculated differently. All the emergency care activities performed by the GP post and the ED are discussed in more detail in paragraph.

3.2.1. Patient inflow – GP post

The GP post's function is to operate as first access point to the out-of-hours emergency care. Patients are recommended to make a telephonic appointment in order to improve the GP post's operational performances. However, patient can still choose to contact the GP post directly by themselves as self-referral. Therefore, two types of physical patient arrivals were faced by the GP post:

1. **Caller:** the patients made an appointment for a GP consult telephonically. There are three different states the patient will arrive in:
    a. The patient receives advice and stays at home;
    b. The patient is visited by a GP at home;
    c. The patient is invited to the GP post for a physical consult.
2. **Self-referral:** the patient arrives unannounced at the GP post directly between 5:00pm and 8:00am during weekdays and the whole day during the weekends;

The type of GP post arrivals were not affected by the integration of the GP post and ED since 2016, only the arrival distributions were changed (Figure 13). The GP post faced more patient arrivals since the organization integrated with the ED in 2016, mainly because of the increased number of self-referrals. The number of patients visiting the GP post physically also increased both absolutely as relatively. The bottom green arrow in Figure 12 represents the patient flow entering the IEP via the main entrance for a physical GP consult.

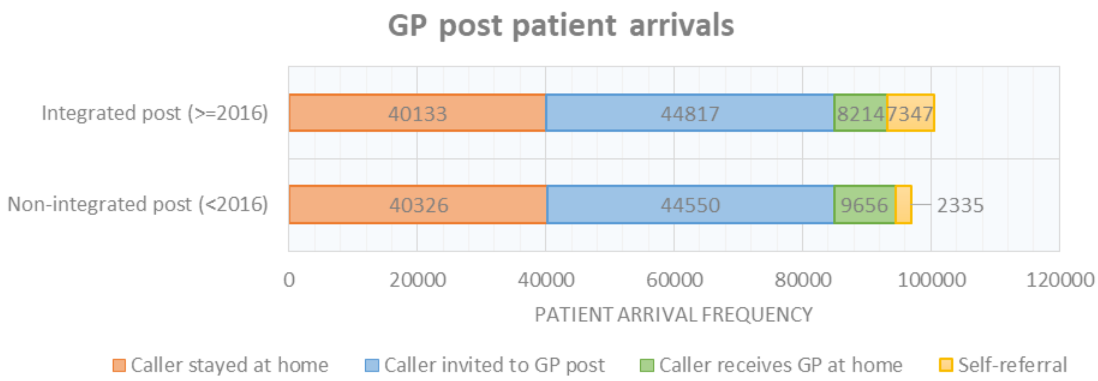


Figure 13: GP post patient arrival distribution before and after the integration of the GP post and the ED.

3.2.2. Patient inflow – ED

In theory, the ED would only expect the arrival of referred patients, because the department operates as second-line of defense within the emergency chain. Before the implementation of the IEP organization, the separated entrances of the GP post and ED allowed patients to contact the ED directly without contacting the GP post first. However, the GP post and ED shared the same main entrance since January 2016 (Figure 11b), which excluded the arrival of self-referrals at the ED outside of office hours. Nowadays, the ED only faces self-arrivals between 8:00am and 5:00pm during weekdays, because the GP post is closed within these time intervals.

The ED does not only face self-referrals and external referrals, the GP post can also refer patient to the ED for further treatment, which is represented by the yellow arrow in Figure 12 for the IEP organization since 2016. This inter-organizational flow was also possible within the separated emergency organizations between 2014 and 2015, but less visible due to the separated layouts. Therefore, three different types of patient arrivals can be identified for the ED:

1. **Self-referral:** the patient arrives unannounced:
   a. which is possible every day and every hour before integration (2014-2015);
   b. during office hours only since the IEP organization in 2016 and 2017.
2. **GP post referral:** an arrival originating from the GP post:
   a. between 5:00pm and 8:00 am on workdays;
   b. during the weekends, the whole day.
3. **External referral:** the patient is referred by its own GP or a medical specialist:
   a. the patient is referred by its own GP during office hours;
   b. the patient is referred by an internal or external medical specialist;
   c. the patient is brought by ambulance, police or trauma helicopter.

The distinction between self-, GP post and external referrals is essential in order to model the characteristics of the arriving patients properly. However, another classification of the arriving patients is applied within the ED in order to make the staff allocations. Therefore, the ED patients are also classified into two alternative groups:

1. **Labeled patients:** these patients are referred to a given specialism by a GP (during office hours) or an internal/external specialist (Koster, 2014). The resident of the specialism allocated will take care of the patient;
2. **Unlabeled patients**: these patients are not directly referred to any type of specialism and are first seen by an emergency physician. The unlabeled patients include all the ED's self-referrals and the patients who are brought to the ED by ambulance, trauma helicopter or by the police (Koster, 2014).

Please notice that the labeled classification is unique to the ED in Enschede, other cities do not include these type of patient categories. For example, the ZGT hospital in Almelo also made use of the simulation model proposed by Bruens & Mes (2012), but the additional label was not required for the resource allocations.

The distribution of patient type arrivals changed over the years (Figure 14). Since the integration of the GP post and the ED, the number of self-referrals at the ED decreased, resulting into an absolute and a relative decrease in the number of unlabeled patients. The ED only faces self-referrals during the regular office hours, because the GP post is then closed. These changes has implications for the staff allocations of both the physical triage and the anamnesis, which will be discussed in Section 3.3.4.

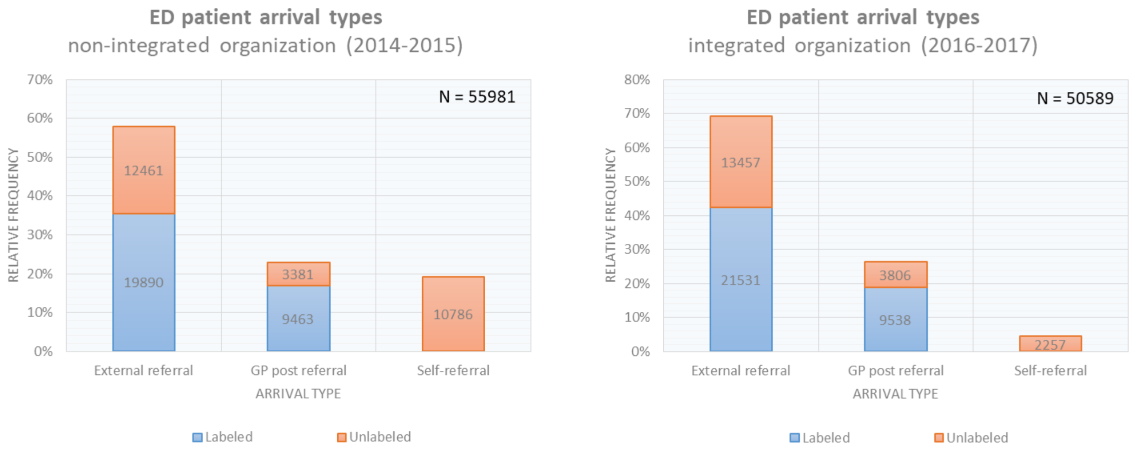


Figure 14: ED patient arrival distribution in front the anamnesis activity before (left) and after (right) the integration of the GP post and the ED since the 11th of January 2016. The ED self-referrals only arrive during office hours within the integrated organization in between 2016 and 2017, the GP post is responsible otherwise.

3.2.3. Patient outflow – GP post

The patient's flow out of the GP post consist of three categories for both the separated and integrated organization of emergency care:

1. **Home:** the complaints are adequately treated and the patient leaves the IEP;
2. **ED referral:** patient requires access to secondary emergency care for further treatment;
3. **X-ray referral:** the patient is send to the radiology department to scan for bone fractures:
    - **a.** if bone fractures are observed, the patient is admitted to the ED directly;
    - **b.** otherwise the patient goes home anyway.

Most patients can go home after a GP post consult (Figure 15). If the GP post cannot treat the patient's complaints adequately, the GP post can also refer patient to the ED for further treatment. The patient is referred to the radiology department if the GP suspects that the patient has one or more bone fractures, otherwise the patient may go home. This inter-organizational flow is represented by the yellow arrow in Figure 12 for the IEP organization since 2016. Please notice that the patient can visit any type of external department in order to conduct one or multiple diagnostic tests. The X-rays are included only, because of its relative high frequency.

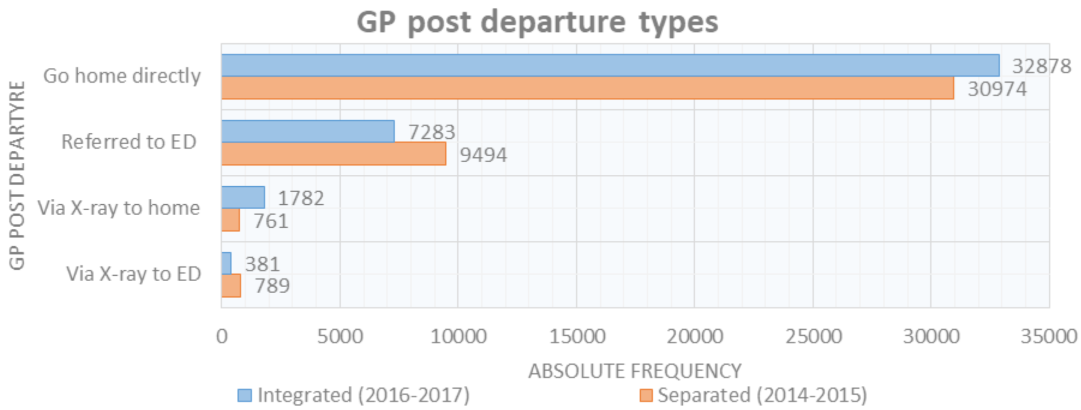


Figure 15: GP post patient departure distribution before and after the integration of the GP post and the ED. Only the patient that physically visited the GP post are included within this figure, other patient mainly remain at home.

The number of patients referred to the ED immediately have decreased since the integration. An increase was expected due to the larger group of self-referrals arriving at the GP post. Secondly, the number of patients referred from the GP post consult to the radiology department has increased since the 11th of January 2016, but that the number of patients from the radiology department referred to the ED reduced both absolutely as relatively. This could indicate a relative high false positive rate at the physical GP consult's diagnostics.

3.2.4. Patient outflow – ED

The patients' flow out of the IEP also consists of three main categories, represented by the red arrows in Figure 12:

1. **Home:** the complaints are adequately treated and the patient leaves the IEP;
2. **Admission:** the patient is admitted into the hospital (MST Enschede);
3. **Transfer:** the patient is transferred to another hospital;
4. **Death:** the patient passed away at the ED and is send to the mortuary.

The ED can discharge patients, if and only if the patient's complaints are treated adequately. These type of patients will leave the IEP via the main entrance. If the patient's conditions are stabilized but still requires further treatment, he or she will be admitted into the hospital. Most of the patients go home directly, but a relative large group of patients is also hospitalized (Figure 16). However, the relative proportion of patients admitted into the hospital relatively increased since the integration of the GP post and the ED. The patient can also be transferred to another hospital, but the frequency of this patient outflow is relatively low because of the MST hospital offers high complex care. The number of deaths at the ED is also extremely low in comparison with the total population.

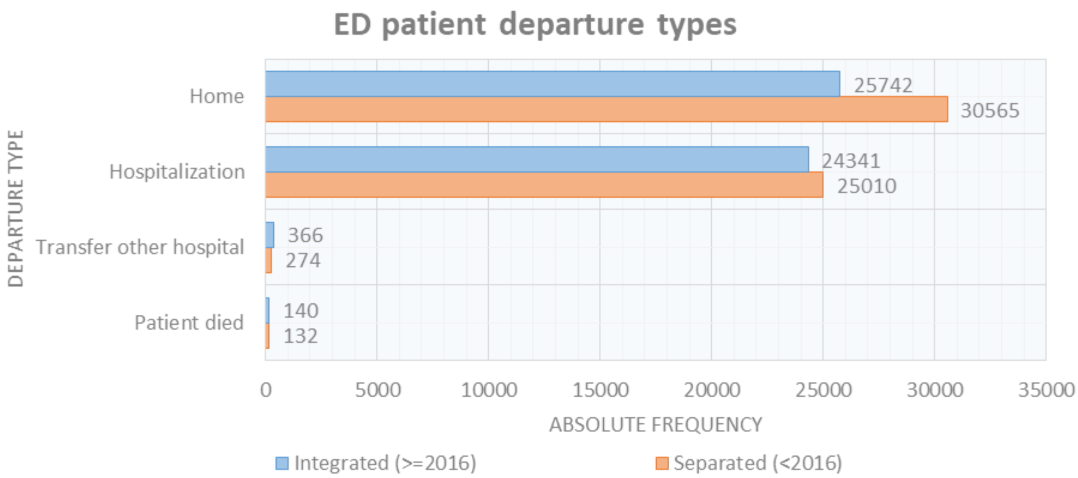


Figure 16: ED patient departure distribution before and after the integration of the GP post and the ED.

3.3. IEP process description

Two separate stakeholders are taken into consideration within this research for the out-of-hours emergency care: 1) the GP post and 2) the ED. Therefore, it seems logical to describe the processes for these stakeholders separately, both for the separated organization from 2014 to 2015 and the integrated organization from 2016 to 2017. An additional description of the "patient admittance" process is given, which includes all activities that precede the physical arrival of patients within either the GP post or ED (Mes & Bruens, 2012). The three process classifications are defined as following:

1. **Patient admittance**: this main process forms the entry point for either the GP post or ED and consists of both telephonic and physical triage of the new patient;
2. **GP post activities**: the out-of-hours care provided by the GP post staff, consisting of 1) providing advice; 2) visiting the patients at home and 3) giving consultations.
3. **ED activities**: the out-of-hours care provided by the hospital's emergency department, consisting of 1) anamnesis; 2) diagnostics and 3) the actual treatment (Koster, 2014).

These three process classifications are discussed in more detail in the following subsections, but the overall process flow diagrams are given first.

3.3.1. *Process flow diagrams*

Figure 10 represented the separated organization of the out-of-hours emergency care in Enschede from 2014 to 2015. The GP post's function is to operate as gatekeeper to the out-of-hours emergency care, while the ED operates as secondary defense. Patients are recommended to contact the GP post by telephone first, but patients can also refer themselves unannounced to either the GP post or ED. Therefore, both stakeholders include triage activities in order to decide which patients may enter the facilities. The GP post can refer a patient for further treatment to the ED, but the processes of both organizations are strictly separated from each other due to the disjunctive locations of both stakeholders. Figure 17 visualizes the separated emergency care organization.

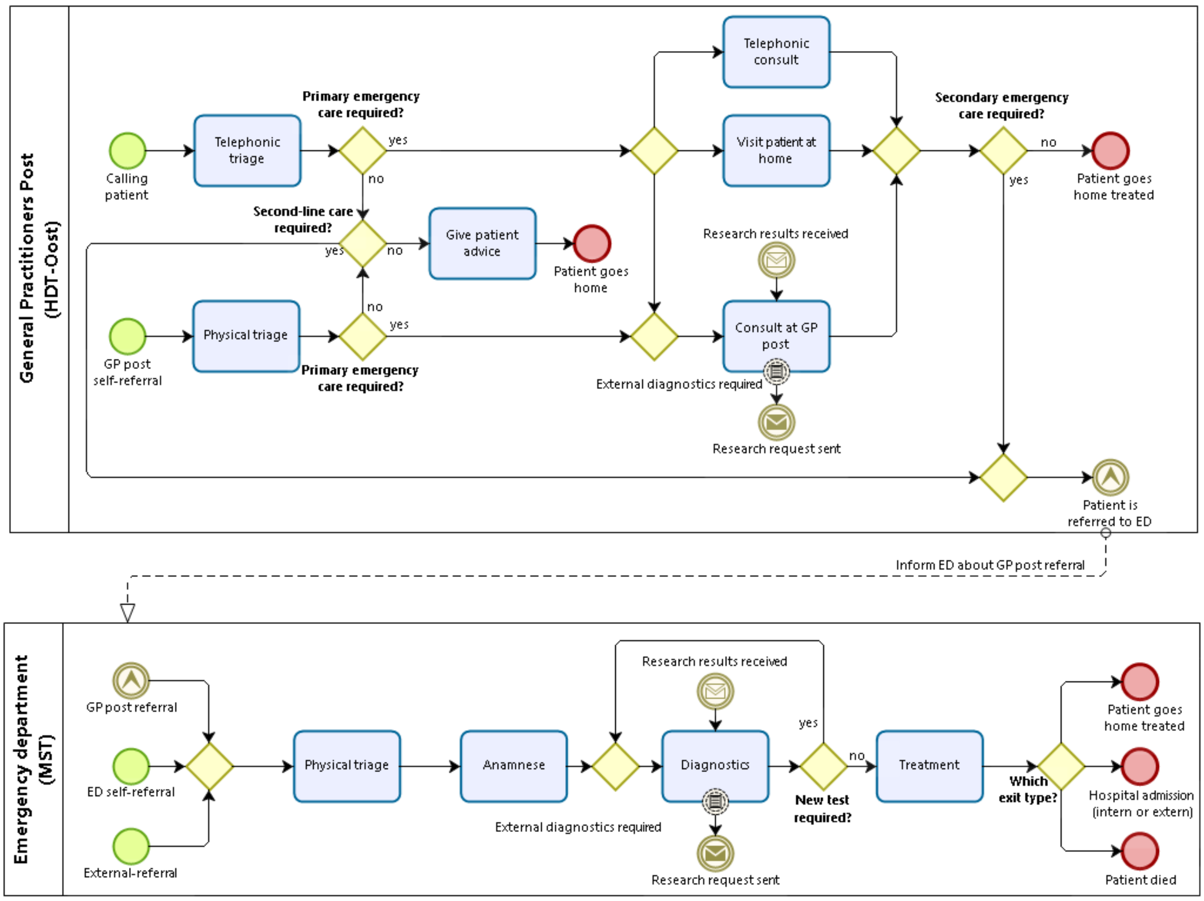


Figure 17: Process flow diagram from the separated organization of the emergency care in Enschede from 2014 to 2015.

Since the integrated organization is implemented in 2016, both the GP post and the ED have the same main entrance (Figure 11). The out-of-hours patients call the GP post first in order to request access to emergency care. It is still possible for self-referrals to arrive unannounced, but nowadays the GP post is fully responsible for the patient admittance process during out-of-hours. The patient's urgency level is determined by the GP assistant first, based on the entrance complaints provided by the patient itself. Secondly, the GP assistant determines whether it is sufficient to given the patient advice, otherwise the patient is invited to visit the GP post or ED. A visualization of the integrated emergency care organization is given by Figure 18.

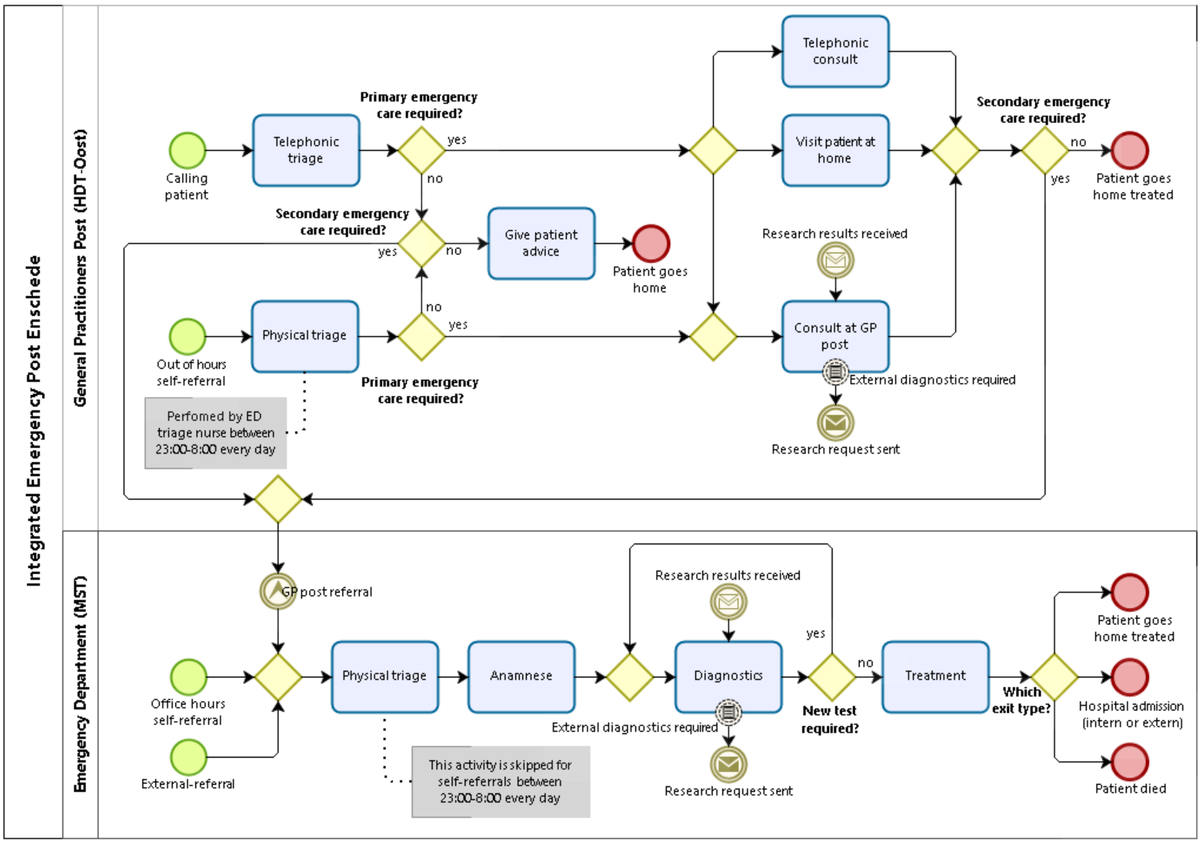


Figure 18: Process flow diagram from the integrated organization of the emergency care in Enschede from 2016 to 2017.

Most of the activities corresponding to the out-of-hours emergency care remained the same for both the separated and the integrated organization. Both stakeholders include triage activities, the GP post can still provide the patient with advice, visit the patient at home or invite the patient for a physical consult and the ED's successive execution of the anamneses, diagnostics and treatment remained unchanged. However, some differences between the separated and integrated emergency care organization can be identified by examining Figure 17 and Figure 18 more closely:

1. First of all, the locations of the GP post and the ED are not strictly separated anymore. The IEP can be seen as one location, which shelters two different stakeholders. Patients can be sent from the GP post to the ED directly, without leaving the building as before;
2. The GP post is now fully responsible for the triage of all out-of-hours patient arrivals. Calling patients and self-referrals are first helped by the GP assistant during the telephonic or physical triage respectively;
3. The GP post and ED work more together during the physical triage at night. All arriving self-referrals that arrive between 11:00pm and 8:00am are seen by the triage nurse from the ED. If the patient is sent to the ED, the patient does not have to undergo the physical triage by the same nurse twice.

Note that the ED did not fully eliminate the physical triage activity. One should expect that the patient's urgency level should be determined only once, this is not the case however. All patients entering the ED are first seen by a nurse that executes the triage, whether the patient already visited the GP post or not. Physical triage is only performed once for all self-referrals that arrive at night, because the ED triage nurse is than supporting the GP post with this activity.

3.3.2. The patient admittance process

Patient admittance ensures that all patients receive the care they require. The triage nurse tries to describe the patient's condition based on the complaints and symptoms given, without focusing on a diagnosis yet (Nederlands Huisartsen Genootschap, 2016). Triage can be seen as a dynamic process in order to determine the patient's urgency level and follow-up action. Both the GP post and the ED make use of a triage decision support system in order to determine the patient's urgency level and follow-up action required. Nowadays, the GP post and the ED make use of the same standardized system, the "Nederlandse Triage Standaard" (NTS). Triage nurses use the NTS in order to categorize all arriving patients into six different urgency levels, resulting into different maximum waiting times allowed for each level. An overview of the urgency levels is given within Table 3, including the maximum waiting times for each urgency level.

Code	Color	Title	GP post max waiting time	ED max waiting time
U0	Red	Resuscitation	0 minutes	0 minutes
U1	Orange	Life threatening	15 minutes	10 minutes
U2	Yellow	Emergency	60 minutes	60 minutes
U3	Green	Urgent	180 minutes	120 minutes
U4	Blue	Not urgent	∞ minutes	240 minutes
U5	White	Advice	∞ minutes	Not applicable

Table 3: Different urgency levels used within the "Nederlandse Triage Standaard", including the maximum waiting times.

Both organizations interpret the urgency classifications resulting from the NTS decision support system differently. The GP post's triage nurses make use of all six NTS classifications available, while the ED triage nurses do not recognize any U5 (white) patients. The ED patients are classified into five different urgency classifications, based on the "Manchester Triage System" (MTS) previously used by the ED within the separated organization from 2014 to 2015. Therefore, the U0 patients included within the ED patient records do not represent the classifications' definitions in Table 3, but represent a missing input value. The different interpretation partly explains why both organizations use different triage decision support systems.

Figure 19 visualizes the urgency classifications allocated by the GP post and ED before and after the integration, while a more detailed description is given in Appendix C. Most urgent patient (U0, U1 and U2) are treated by the ED, while less urgent patients (U3, U4 and U5) visit the GP post instead. The number of non-urgent patients visiting the ED seems to be too small in the years 2014 and 2015, especially if you take into account that self-referrals could visit the ED without contacting the GP first. The total number of urgent patients contacting the GP post increases over the years, while the number of ED patients decreases for all urgency classifications available. Finally, a relative large part of patient records do not include any classification at all.

3.3.3. The GP post's processes

During the patient admittance process, the GP assistant determined which urgency level and follow-up action are required in order to treat the patient adequately. Non-urgent patients are given medical advice most of the times, while life threatening cases are sent to the ED immediately. All other patients require additional resources from the GP post. The process flow diagram in Appendix D visualizes all the GP post's activities required, including the staff allocations, decision nodes and time measurements.

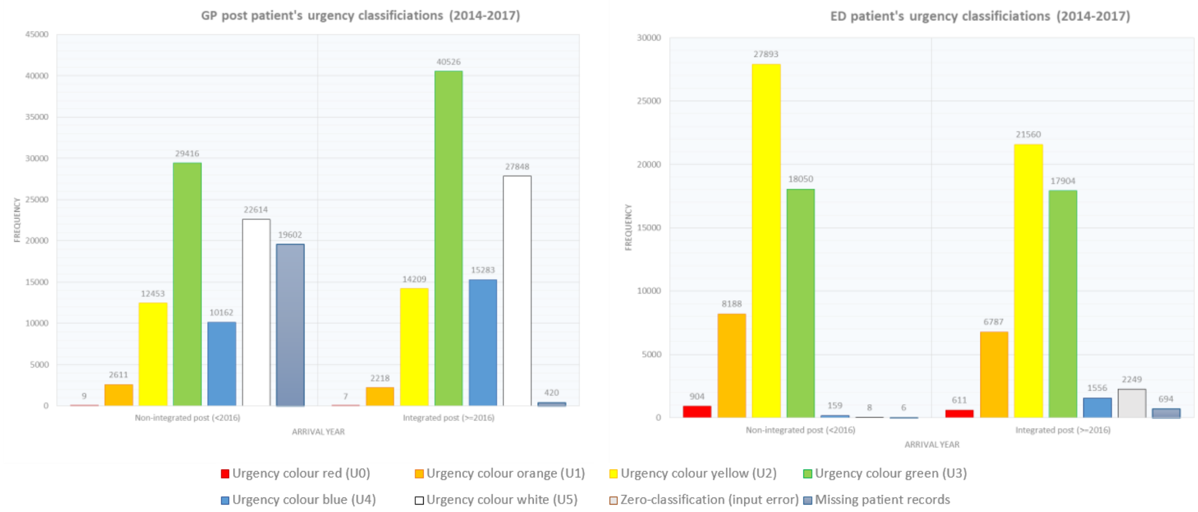


Figure 19: A visualized distribution of the patients' urgency colours allocated by the GP post (left) and the ED (right). The urgency allocations before and after the integration of the GP post and ED are compared.

The process flow diagrams in Section 3.3.1 revealed that the GP post's main activities remained the same since the integration of the GP post and ED in 2016. Three activities can be defined:

1. **Telephonic consult:** a GP will call back the patient in order to discuss the complaints telephonically. If the patient's complaints aren't solved adequately, the GP can still decide to invite the patient to the GP post for a physical consult;
2. **Visit the patient at home:** it is possible that a patient is unable to move, while the patient's complaints should be examined by a GP. In these cases the GP can visit the patient at home;
3. **GP consult:** the most common way to examine the patient's complaints is to invite the patient for a physical consult. An appointment is made for the patient's arrival. The patient is referred to the GP post's waiting room, where the patients are prioritized based on a combination of the urgency classification given during triage and the patient's waiting time.

The GPs also have to authorize the decisions made by the GP assistants during both telephonic and physical triage. A directing GP is hired for these authorizations between 7:00pm and 22:00pm every day in order to relax the other GPs.

New organizational experiments are conducted within the GP post over time. For example, the physical consult can also be performed by a GP assistant or nursing practitioner (NP) more frequently. These staff members can take over some consults from the GP, which makes it possible to reduce the GPs' workload. Therefore, two additional activities are taken into consideration within the integrated emergency organization:

1. **GP assistant consult:** the GP assistant takes over minor treatments from the GP. The GP assistant is only available for consults during the weekend between 9:30am and 10:00pm;
2. **NP consult:** the NP takes over specific complex complaints from the GP, especially bone fractures. The NP is only available during the weekend between 10:00am and 6:00pm for three times per month.

Figure 20 visualizes the frequencies of all actions selected for both the separated organization from 2014 to 2015 and the integrated organization from 2016 and 2017. A total of 96.867 patients contacted the GP post before the integration in 2016, while the number increased to 100.094 patients since the GP post and ED were integrated. This increase was expected due to the self-referrals that are enforced to contact the GP post nowadays. The number of GP consults and GP visits at home decreased after the integration, while the number of GP assistant consults and NP consults increased. More patients are also provided with advice, preventing them from visiting the GP post or ED unnecessarily. On the other hand, more patients are referred to the ED immediately.

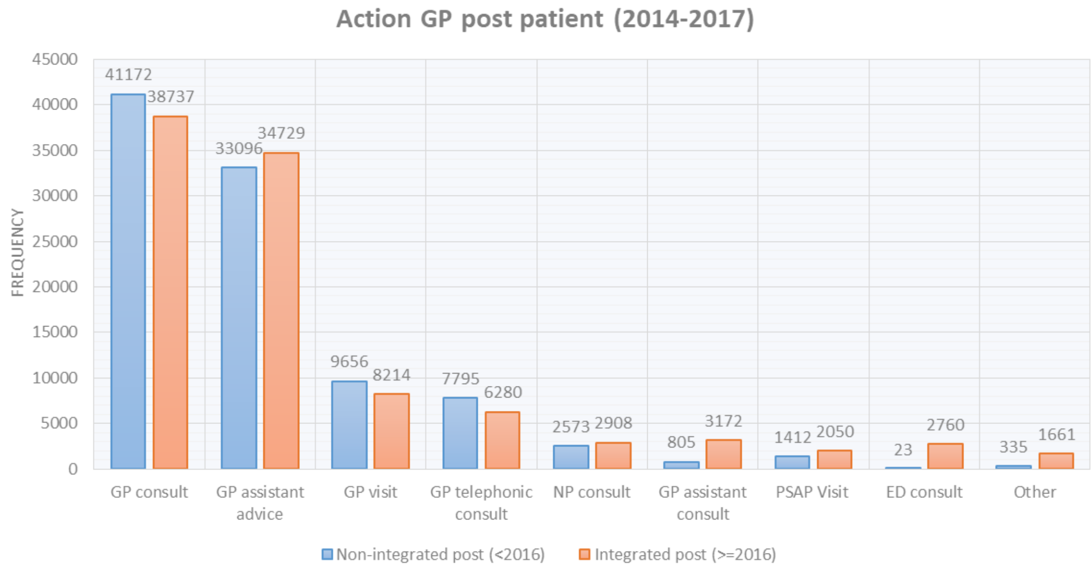


Figure 20: Frequency overview of the actions selected by the GP assistants during both telephonic and physical triage. The data is separated for the non-integrated and integrated emergency post.

3.3.4. The ED's processes

The discussion in Section 3.2.2 revealed that three type of patients can enter the ED: 1) a self-referral; 2) a GP post referral and 3) an external referral. An emergency patient is always brought to the ED immediately by the emergency services, while the GP post referral and external referrals first consult the patient by themselves and refer the patient to the ED secondly. Self-referrals can still arrive at the ED during office hours when the GP post is closed. Once the patient arrives at the ED and its urgency level is determined by an ED nurse during the triage activity, the patient is treated in three different steps: 1) anamnesis; 2) diagnostics and 3) the actual treatment (Koster, 2014). The process flow diagram in Appendix D visualizes all the ED's activities required, including the staff allocations, decision nodes and time measurements.

The patient's symptoms and medical history are first discussed during the anamneses. Labeled patients are helped by a resident, while all unlabeled patients are visited by the emergency physician (see the discussion in Section 3.2.2). The emergency physician is not present at the ED during the night, the unlabeled patients are than helped by the surgery or orthopedics resident. Both the resident and emergency physician are supported by one or more ED nurses during the anamnesis. A relative decrease in the number of unlabeled patients is observed since the integration of the GP post and the ED, which indicates a workload shift from the emergency physician to the residents.

The anamneses is followed up by the request, execution and review of one or multiple diagnostic tests. If the patient is labeled, the responsible resident will determine which diagnostic tests are required, the emergency physician will do the same for all unlabeled patients. The five diagnostic tests most frequently requested by the ED are taken into account:

1. **X-ray:** the X-ray pictures are taken by a diagnostic employee from the radiology department. The pictures can be made by one of the two X-ray installations installed at the ED, otherwise the patient is brought to the radiology department itself;

2. **CT scan:** the CT scan is conducted by a diagnostic employee from the radiology department. The scans are made at the diagnostic room at the ED itself, which includes one CT scanner;
3. **Ultrasound:** the ultrasound equipment is installed and used by a diagnostic employee from the radiology department. Multiple ultrasound resources are available at the ED and can be used at all the ED's treatment rooms.
4. **Lab research:** the samples, research and review activities are conducted by a diagnostic employee from the "Medlon" laboratory organization, which is located in the building of the MST hospital. The samples can be taken in all the ED's treatment rooms, even in the waiting room if necessary;
5. **ECG:** the ECG equipment is installed and used by a diagnostic employee from the cardiology department. Multiple ECG resources are available at the ED and can be used at all the ED's treatment rooms.

The type of diagnostic tests requested depends on the patient's characteristics. For example, a patient with cardiac arrhythmia would probably require an ECG, while bone fractures are better visualized by the allocation of X-ray equipment. 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 test are requested (Koster, 2014).

Once the diagnosis is completed and the patient's illness became clear, the patient is actually treated by the resident or emergency physician. A treatment plan is developed and executed by the staff member responsible. However, the serial process from diagnosis to treatment may be obstructed by three types of interruptions:

1. **Diagnostic rework:** it may be possible that the diagnostic test provide other results than hypothesized by the ED resident or emergency physician, which may include a new request of diagnostic tests.
2. **New specialist allocation:** the test results may reveal another type of illness than hypothesized, which may require the transfer of responsibility to another specialist type;
3. **Specialist support:** it may be possible that the resident or emergency physician is unsure about the patient's treatment plan, which allows them to contact a medical specialist telephonically in order to ask for advice. It is even possible that the medical specialist comes to the ED itself, performs additional diagnostic tests and treats the patient.

In the end, the patient is treated by a resident of the specialist type corresponding to the patient's complaints. It is also possible that the emergency physician may performed the treatment itself. There are 23 different types of specialisms registered within the period from 2014 up to 2017. Most ED patients are treated by six different types of specialists: 1) Surgery; 2) Internal medicine; 3) Orthopedics; 4) Pulmonary medicine; 5) Neurology and 6) Gastrointestinal & liver. Almost the half of all patients is treated by surgery, which forms the largest group of all (Figure 21). The number of surgery and orthopedic patients decreased over the years, while all other specialist types increased both absolutely and relatively.

3.4. IEP resources

Both the GP post and ED have two important resources: 1) the room capacity and 2) the staff members available for the treatment of patients. Each patient is allocated to a specific room and one or more employees, which depends on the patient's entrance complaints. The room capacity, staff member types and resource allocations will be discussed in more detail within this paragraph.

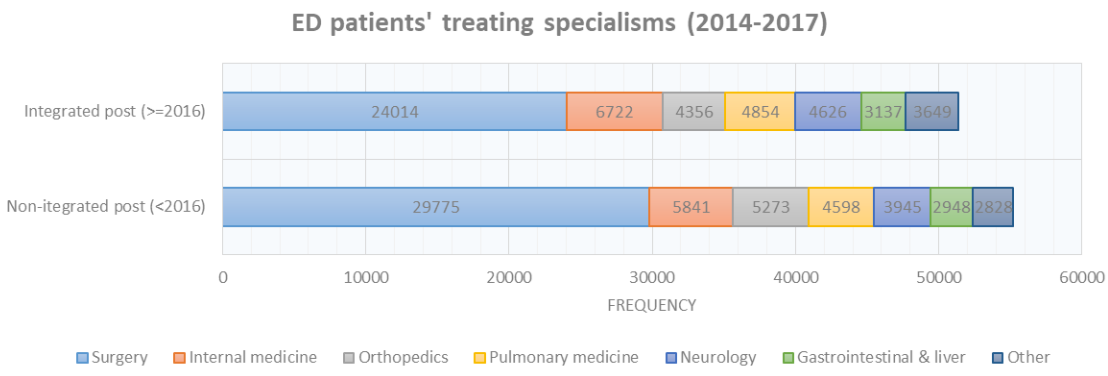


Figure 21: Absolute frequencies of the ED treating specialisms for the separated and integrated emergency care.

3.4.1. Room capacity

The room capacity is strictly separated for both organizations, both before and after the integration of the GP post and ED since the 11th of January 2016. The type of rooms used did not change since the integration, only the number of rooms increased in both organizations. Therefore, the integrated room layout is only used in this validation and optimization research. Comparisons with the room layout originating from the years 2014 and 2015 would reduce the logistic KPIs only because of the limited capacity back then, which makes it impossible to evaluate the IEP's actual performances.

The IEP layout in Figure 12 indicates that the number of rooms that the GP post and ED share is very limited, only two triage rooms are used by both organizations, including the waiting area in front of these rooms. The GP post consists of four examination rooms for standard GP consults and two treatment rooms enabling small medications (Table 4), while the ED provides a room capacity for parallel treatment of twenty-two patients in total. Six rooms are installed for general ED treatments, while the remaining sixteen rooms are dedicated for some special type of patients. Detailed visualizations of the GP post and ED layouts are given in Appendix E.

Organization	Room type	#rooms	Characteristics
IEP	Triage room	2	• Physical triage only, can also be used for blood testing • Both rooms are used by ED and GP post
	Waiting room	1	• Small waiting room for self-referrals
GP post	Consultation room	4	• Standard room for GP consults
	Treatment room	2	• -
	Waiting room	1	-
	Trauma room	2	• X-ray equipment available in both rooms
ED	Acute room	2	• Resuscitation equipment available in room 3
	Diagnostic room	1	• CT scan equipment available
	Plaster room	2	• -
	Treatment room	11	• 3 dedicated children rooms (7, 8 & 9) • 1 dedicated burns room (14) • 1 dedicated ear, nose and throat room (19)
	Fast-track room	1	• Dedicated for minor treatments • Contains 3 treatment chairs (10A, 10B & 10C)
	Barrier room	2	• Room IK 15 contains air pressure control system • Room DK 20 is used for contaminated patients, the room is located outside the ED
	Family room	2	• No treatment room, only used to temporarily accommodate family, friends and others involved
	Farewell room	1	• No treatment room, only used for patients who passed away
	Waiting room	2	• One waiting room is dedicated for children

Table 4: Available room capacity within the IEP Enschede after the integration of the GP post and ED since the 11th of January 2016. Under normal circumstances, only one patient could be allocated to each room at the same time.

3.4.2. IEP personnel

All staff members are employed by the GP post or the ED individually, which indicates that the two organizations still operate independently from each other. An overview of all staff positions employed within the IEP Enschede is given in Table 5, including the corresponding task descriptions. The staff rosters are for both organizations are represented in Appendix F.

Organization	Personnel type	Task description
GP post	General practitioner (GP)	Performs consultations at the GP post and visits patients at home
	Coordinating GP	Supports the triage performed by the GP assistants
	GP assistant	Performs telephonic and physical triage
	Coordinating GP assistant	Coordinates the triage performed by the GP assistants
	Circulating GP assistant	GP assistant responsible for relative small treatments
	Nurse practitioner	Treats specific patient groups
	Receptionist	Receives patients upon arrival at the GP post
	Car driver	Specialist driver responsible for the patient visits
ED	Receptionist	Receives patients upon arrival
	Triage nurse	Performs physical triage for all self-referrals
	Coordinating nurse	Coordinates progress and execution of care and patient flow. Allocates patients to ED rooms
	ED nurse	Nursing examination and care
	Emergency physician	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 come to the ED to perform diagnostic tests

Table 5: Task descriptions of the available staff positions within the IEP's GP post and ED.

3.4.3. Resource allocations

Section 3.3 provided an overview of the main processes and activities within the GP post and the ED. All activities require one or more resources like staff members and treatment rooms. Table 6 provides an overview of all resource requirements per activity for the GP post, the ED and the external diagnostic departments.

3.5. IEP organization conclusions

The emergency care organization in Enschede in chapter 3 is described for two situations: 1) the separated provision of emergency care before integration in 2014-2015 and 2) the emergency care after integration of the GP post and ED in 2016-1017. Three main process classifications identified for both the separated and the integrated organization:

1. **Patient admittance**: this main process forms the entry point for either the GP post or ED and consists of both telephonic and physical triage of the new patient;
2. **GP post activities**: the out-of-hours care provided by the GP post staff, consisting of 1) providing advice; 2) visiting the patients at home and 3) giving consultations.
3. **ED activities**: the out-of-hours care provided by the hospital's emergency department, consisting of 1) anamnesis; 2) diagnostics and 3) the actual treatment (Koster, 2014).

Alternative patient care pathways are identified for the GP post arrivals, GP post physical consult departures, ED arrivals and ED departures. The care pathway allocated depends on the NTS urgency classification assigned to the patient. If the patients requires physical treatment by either the GP post or the ED, several resources should be allocated before starting the next activity (room, staff and diagnostic resources). ED patients are also allocated to a treatment group for proper staff allocations, the emergency physicians are allocated if the patient arrives unannounced or by ambulance.

Organization	Activity	Staff required	Room required	Additional resources
GP post	Telephonic triage	GP assistant	Call center	NTS decision support
	Physical triage	GP assistant	Physical triage room	NTS decision support
	GP physical consult	General practitioner	Treatment room	-
	GP visit	General practitioner	-	GP post car
	GP telephonic consult	General practitioner	Consultation room	-
	NP consult	Nurse practitioner	Consultation room	-
	GP assistant consult	GP assistant	Consultation room	-
ED	Physical triage	ED nurse	• Triage room • Trauma room (112 only) • Acute room (112 only) • Treatment room (112 only)	NTS decision support
	Anamnesis	• Emergency physician (unlabeled) • Resident (labeled) • ED nurse (for support)	• Trauma room • Acute room • Treatment room	-
	Review diagnostics	• Emergency physician (unlabeled) • Resident (labeled) • Medical specialist (if required)	Central workplace	Diagnostic results
	Treatment	• Emergency physician (if allowed) • Resident • Medical specialist (if required)	• Trauma room • Acute room • Treatment room	-
	Plaster	ED nurse	Plaster room	-
External diagnostics	X-ray	Diagnostic employee	• Trauma room • X-ray department	X-ray equipment
	CT scan	Diagnostic employee	Diagnostic room	CT scan equipment
	Ultrasound	Diagnostic employee	• Trauma room • Acute room • Treatment room	Ultrasound equipment
	Lab research	Diagnostic employee	• Waiting room • Triage room • Trauma room • Acute room • Treatment room	-
	ECG	Diagnostic employee	• Trauma room • Acute room • Treatment room	ECG equipment

Table 6: Resource allocations for the GP post, ED and external departments responsible for diagnostics.

Chapter 4 – The conceptual model

The main aim of this research is to gain insights into the effects of integrating the GP post and the ED in order to improve the (out-of-hours) emergency care in Enschede. An updated description of the real-world's problem context should be given first, which can be used as basis for the development of a simulation model. The changes observed will help to answer the fourth research question:

Research question 4: How do the processes, patient flows and resource allocations within the IEP Enschede differ between the expectations from 2014 and the actual organization today?

In this chapter, a conceptual model of the real world's processes is defined to develop a valid and credible simulation model (Law, 2015). Robinson (2004) defined the conceptual model as:

Quote (Robinson, 2004): *"The conceptual model is a non-software specific description of the simulation model that is to be developed, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model".*

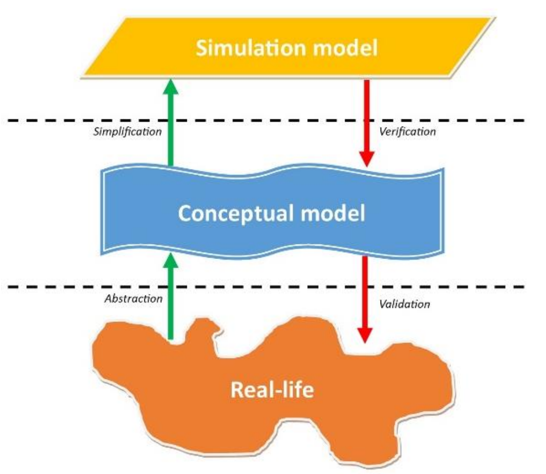


Figure 22: A simplified representation of the translations required within a simulation study. Two levels of abstraction are included: 1) the translation from the real-life problem context to an understandable conceptual model and 2) the implementation of simplified decision logic into the simulation software. Note the different "roughness" of the models, which represent the simplifications made per translation. Verification and validation activities are required to evaluate if the translations are executed correctly.

The conceptual model can be seen as the first blue-print of the simulation model to develop, resulting in an abstraction from all the patients, processes and resources most frequently seen by the organizations in real life (Figure 22). The process descriptions in Chapter 3 already revealed the first abstraction of both the separated and integrated emergency care organization in Enschede. In this chapter, the conceptual model is extended by describing the: 1) simulation goals; 2) input variables; 3) output variables; 4) assumptions and 5) simplifications.

4.1. Simulation goals

The main aim of this research is to gain additional insights into the actual performances of integrating the GP post and the ED first. Therefore, the expected results gained during the simulation study of Koster (2014) should be compared with the actual results obtained from both the GP post and ED patient records gathered since the 11th of January 2016.

The simulation model's input variables and the resource allocations changed over the years. Therefore, the simulation model developed by Koster (2014) should be updated in order to make useful comparisons. The conceptual model will help to define which input variables, process descriptions and resource allocations are changed.

4.2. Input variables

The most important input variable in this research is represented by the decision to integrate the GP post and the ED or not. Furthermore, the changes in the IEP's input parameters and organizational choices should be investigated in order to validate the solution implemented:

1. **The number of patient arrivals:** includes both the total number of patient arrivals that changed over the years, but also the arrival rates per hour, day and week;
2. **The type of patient arrivals**: The GP post includes two types of patient arrivals: a) callers and b) self-referrals. The ED has three type of patient arrivals: a) external referrals; b) GP post referrals and c) self-referrals. The frequencies of all these patient types changed since the integration of the GP post and the ED, especially the ratio of self-referrals;
3. **The arriving patients' characteristics**: the patient's attributes describing its medical condition like entrance complaints, age, etc.;
4. **The activities taken into consideration**: the type of processes executed slightly changed since the integration of the GP post and the ED, as given by the process descriptions in chapter 3 *"Out-of-hours emergency organization"*;
5. **The activities' durations**: the estimated duration of all activities, most staff members experience an increased duration for all type of activities which should be evaluated;
6. **The resource allocations**: the type and number of staff members, treatment rooms and diagnostic tests required for each activity;
7. **The staff rosters**: describes the type and number of staff members available at the GP post and ED at each time of the day;
8. **The request of diagnostic tests**: the type and number of diagnostic test requested at the a) radiology department; b) cardiology department and/or c) laboratory.

The values corresponding to these input values will be discussed in more detail in Chapter 5. The experiments' input variables are discussed in Chapter 8 once the solution validation is completed.

4.3. Output variables

The integration of the GP post and the ED influences the logistic processes within the IEP Enschede. Therefore, it is reasonable to identify output variables that are related to the logistic performances of both the GP post and the ED:

1. **The patient's length of stay**: the time between the patient's first contact and the actual treatment of its entrance complaints. The length of stay is mainly interesting for the patients' perspective. The length of stay for both the GP post and the ED consists of three different types of time registrations:
    a. The patient's time required for traveling to the IEP Enschede for a physical consult;
    b. The patient's activity durations;
    c. The patient's waiting time in front of each activity.
2. **The resources' utilization rates**: the fraction of the staff's operational time in comparison to the total time scheduled. The resource utilization rates are mainly interesting for the management perspective, they also provide an indication of the staff's workload;
3. **The patient's service levels**: a maximum waiting time is taken into consideration for all urgency classifications. Therefore, a service level can be made which represents the percentage of patients not treated in time.

4.4. Limitations

Limitations are required to reduce the model's complexity, which will benefit the development's speed (Robinson, 2004). Therefore, the model's applicability should be discussed in more detail. The conceptual model's limitations will be discussed within three separate layers, inspired by Robinson (1994). First, the process' constraints will be discussed in order to provide clear boundaries of the emergency care processes given. Secondly, the scope of the model will be explained, including an overview of the activities taken into consideration and the basic assumptions made. Finally, the level of detail will be discussed.

4.4.1. The process constraints

The emergency care activities in Enschede are classified into three main clusters which are completely independent from each other: 1) the patient admittance process; 2) the GP post activities and 3) the ED's activities. The process constraints are also classified into these three clusters, see Appendix G for the full description of all constraints.

4.4.2. The scope of the model

This research investigates the logistic performances of the IEP Enschede only. Other emergency care partners are not taken into account for the performance calculations, but their resources may still be required. For example, patients may by admitted into one of the hospitals inpatient clinics, but the KPIs corresponding to these clinics are not taken into account. The results are also not compared to other emergency services in other cities. This research only includes KPIs that measure the logistic performances described in Section 4.3. Other KPIs like the quality of care are not taken into account. Finally, the ED's performances during office hours is also taken into consideration in addition to previous simulation studies IEP implementations (Visser, 2011; Borgman, 2012; Koster, 2014).

The process analysis in Chapter 3 revealed that some activities are not used that frequently, nor do all activities include significant durations. Therefore, the process descriptions are simplified by eliminating some of the activities within the GP post and the ED. Table 7 and Table 8 explain which activities are included into the development of a simulation model for the GP post and ED respectively. Other resource requirements were already discussed in Section 3.4.

Activity	Staff allocation	Included or Excluded?	Comments
Telephonic triage	GP assistant	Included	The triage durations and results are based on historical data.
Physical triage	GP assistant	Included	The triage durations and results are based on historical data.
Schedule appointment	GP assistant	Included	The appointment scheduling is important for inviting callers to the GP post. The activity itself is assumed to be part of triage however.
Give patient medical advice	GP assistant	Excluded	Assumed to be part of the triage activity.
Approve triage results	Directing GP or regular GP	Excluded	This activity is implicitly included into the patient's characteristics stored within the patient records.
Reschedule patient	Directing GP or regular GP	Excluded	This activity is implicitly included into the patient's characteristics stored within the patient records.
GP consult	Regular GP	Included	The consult duration is based on historical data.
GP visit	Regular GP	Included	The travel and consult duration are based on historical data.
GP telephonic consult	Regular GP	Included	The consult duration is based on historical data.
GP assistant consult	Regular GP	Included	Only included in the integrated out-of-hours emergency care organization since the 11th of January 2016.
NP consult	NP	Included	Only included in the integrated out-of-hours emergency care organization since the 11th of January 2016.
Internal diagnostic test	GP assistant	Excluded	The activity's duration is relatively short, can be performed while the patient is waiting for a consult.
External diagnostic test	Diagnostic employee	Excluded	All diagnostic tests are conducted outside the GP post itself. It is assumed that X-rays are taken at the ED once the patient is referred and if an X-ray is required.

Table 7: An overview of the GP post activities that are included within the model's scope, inspired by Robinson (2004).

4.4.3. Level of detail

The conceptual model is completed by describing the model's level of detail in Appendix H. The main components consist of the patients, room, staff and diagnostic resources. The level of detail for each component is evaluated separately.

Activity	Staff allocation	Included or Excluded?	Comments
Physical triage	Triage nurse or ED nurse	Included	All ED nurses are qualified to perform the triage activity for emergency patients that arrived by ambulance or trauma helicopter. Patients that arrive via the ED's main entrance are seen by a dedicated triage nurse. The physical triage durations are assumed to be the same as for the GP post registrations.
Room & staff allocations	Directing nurse and ED doctor	Excluded	Patients are allocated to an available room and resources are send to the patient once these become available. These allocations are made instantaneously, the request itself is not taken into account.
Anamnesis	ED nurse, ED doctor or resident	Included	The ED nurse initiates the activity and supports further sub processes. The anamnesis is finished by the ED doctor or resident. The durations are based on the assumptions made by Koster (2014).
Diagnostics	ED doctor or resident	Included	The diagnostics are classified into two separated activities: 1) the request and execution of the test itself and 2) the review of the test results by the ED staff members. The reviews made by the diagnostic employees from external departments are not taken into account. The radiology department's diagnostic test durations are based on historical data, while all other test and review activities are based on the assumptions made by Koster (2014).
Telephonic advice	Medical specialist	Included	A resident could call the medical specialist in order to help the resident to define a proper diagnosis of the patient's complaints. The durations are based on the assumptions made by Koster (2014).
Treatment	ED doctor, resident or medical specialist	Included	The treatment's duration is based on assumptions due to limited time registrations. It is possible that ED nurse support the activity. The durations are based on the assumptions made by Koster (2014).
Close file & refer patient	ED doctor or Resident	Excluded	Administrative tasks are not taken into account.

Table 8: An overview of the ED activities that are included within the model's scope, inspired by Robinson (2004).

4.5. Resulting care pathways

Many of the components discussed in the conceptual model are interdependent. For example, high urgency patients will be referred to the ED more often in comparison with low urgent patients, the type of diagnostic test required depend on the type of specialist allocated and the travel time of medical specialists is strongly reduced for life threatening cases. Bruens & Mes (2012) made use of care pathways in order to handle the dependencies between the alternative treatments. Koster (2014) identified four different paths through the IEP Enschede:

1. **Path A:** this includes the alternative care pathways after the patient's arrival. There are also some activities from the GP post included, like the physical triage, telephonic triage, GP visit and the GP telephonic consult. Once the care path is completed, the patient may be referred to: a) home; b) the GP post for a physical consult or c) the ED;
2. **Path B:** this includes the departure types after conducting the GP post's physical consult: a) the patient goes home; b) the patient is referred to the ED or c) the patient is referred to the radiology department (and can be referred home or to the ED after that). Please notice that the physical GP post consult can be allocated to different staff members;
3. **Path C:** the two ED departure types include: a) the patient goes home or b) the patient is admitted into the hospital. Please notice that all patients have to complete the ED consult's four stages before departure: a) physical triage; b) anamnesis; c) diagnostic testing and d) the actual treatment;
4. **Path X:** the ED's external referrals and self-referrals arriving during office hours did not contacted the GP post first. Self-referrals only arrive between 8:00am and 5:00pm during weekdays.

The patient flows in between the four care pathways are visualized in Figure 23.

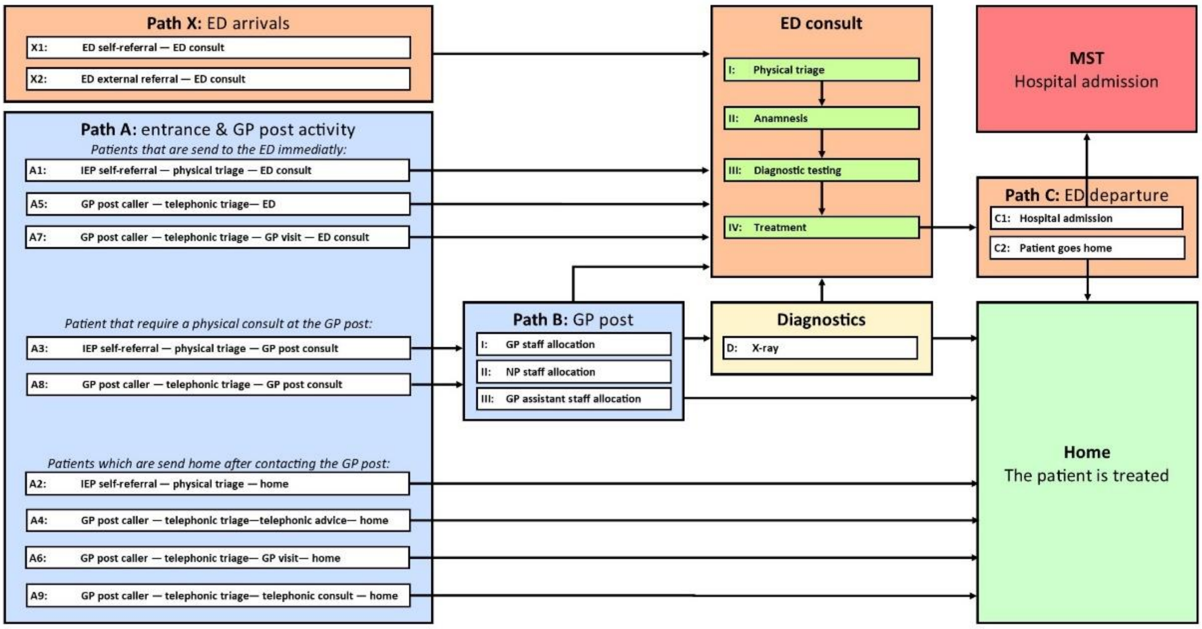


Figure 23: Visualization of the care paths included within the IEP's conceptual model. The blue marked areas represent the care paths within the GP post, while the ED care paths are marked orange. The alternative care paths are white marked, one of these paths is allocated to each patient arriving.

The patient's care pathways are the same as in the conceptual model developed by Koster (2014). However, two adjustments are made in order to include all the IEP processes:

1. A new A-path is added, which includes the GP telephonic consults (A9). There are no patients invited to the GP post physically once the telephonic consult is completed;
2. The staff allocations at path B are added in order to separate the GP consult, NP consult and GP assistant consult from each other.
3. A new X-path, consisting of the ED's self-referrals during regular office hours.

4.6. Creating patients

Koster (2014) initialized the patient's characteristics by successively generating the attributes based on the patient's care pathway allocated and the input distributions obtained from the historical data in the patient records. The decision flow chart in Figure 24 visualizes the way how the patient's attributes are constructed. The dependencies are based on the dependencies already made by Koster (2014). Please notice that the variable's input distributions are updated to the patient records from 2014 up to 2017. There are also some new activities or treatment groups included due to new decisions. However, the internal structure of the variables' dependencies remained unchanged, otherwise the solution validation would include the evaluation of a completely new model. The variables' values are addressed in Chapter 5.

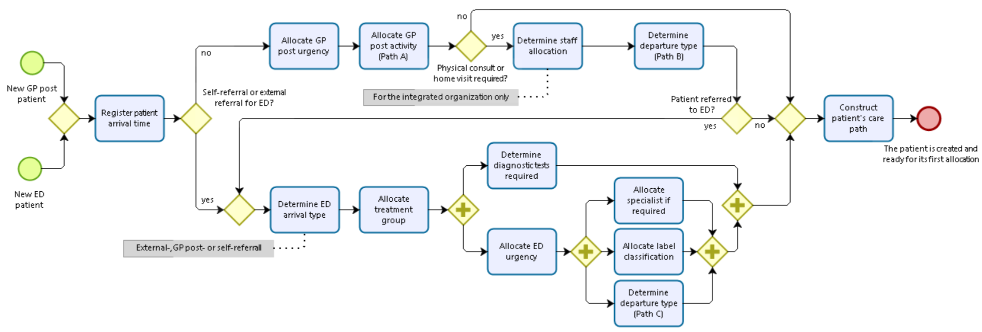


Figure 24: Decision flow chart representing the process of the patient's attributes generation generated once created.

The patient's characteristics are determined immediately after the creation of the patient itself and strongly depend on the patient's arrival time. The interrelationships visualized in Figure 24 are explained in more detail in order to gain insights into the variables' dependencies:

ID	Variables' dependencies
1	The patient's arrival times are registered first, because most attributes depend on the hour, day and/or week of the patient's arrival;
2	If the patient arrives at the GP post, the GP post's urgency classification is determined first, based on the patient's arrival time. The urgency classification is selected first, because the urgency level selected has great influence on the next activity selected;
3	The GP post care pathway allocated (path A) depends on the GP post's urgency classification;
4	If the patient is invited for a consult to the GP post, one of the available staff members should be allocated to the patient. The staff allocation is independent of other variables;
5	The patient's type of departure from the GP post should be determined independently of all other input variables;
6	The patient may be referred to the ED from: a) the GP post; b) by an external party or c) by the patient itself. Once the patients arrives at the ED, the type of arrival is determined. The arrival type frequencies depend on the patient's arrival time;
7	Each patient is treated by a certain type of specialist, depending on the patient's arrival type;
8	The type and number of diagnostic tests required depend on the patient's treatment group;
9	The urgency classifications within the ED depend on the patient's treating specialist. The type of specialist allocated to the patient's treatment depends on the patient's arriving type. Therefore, separate urgency distributions apply to each combination of patient's arrival type and type of specialist allocation;
10	The ED's labeled versus unlabeled classifications depend strongly on the patient's urgency classifications, because a highly urgent patient would probably arrive more often by ambulance than low urgent patients.
11	It is possible for the residents to call a medical specialist for support. This strongly depends on the patient's urgency level allocated, the more important the patient, the sooner the medical specialist will arrive at the ED.
12	The change that the patient should be hospitalized depends on the patient's urgency classifications. The higher the urgency level, the more likely it is the patient is admitted into the hospital.

Table 9: The dependencies between the variables required for the generation of new patients.

4.7. Conceptual model conclusions

This chapter provided an overview of the out-of-hours emergency care components taken into consideration for the simulation model validation and optimization. First the simulation model developed by Koster (2014) is updated in order to make useful comparisons with the system's actual performances. The most important input variable in this research is represented by the decision to integrate the GP post and the ED or not. Second, the changes in the IEP's input parameters and organizational choices should be investigated in more detail (Chapter 7). The patient's length of stay, the resource utilization rates and the patients' service levels are used as KPIs for the soluation validation. The modifications made in comparison with the initial model of Koster (2014) are visualized in Table 10.

Once again, note that the simulation model is extended to evaluate the ED's regular office hours also. Koster (2014) focused only on the simulation of the out-of-hours for both the GP post and the ED. Therefore, the simulation results should be compared with care.

Component	Sub-component	Modification of the conceptual model
Patient	Arrival type	1. The first A-path consists of IEP self-referrals that are send to the ED immediately, only the physical triage is executed by the GP post; 2. The GP post referrals may also include unlabeled patients; 3. The IEP Enschede is simulated 24/7. Therefore, self-arrivals may be directed to the ED once the GP post is closed, resulting in a new X-path; 4. The number of external referrals to the ED resulted to be higher than expected;
	Arrival rate	1. Only the input parameters are changed, there are no structural modifications required; 2. The number of GP post patients increased because of the increased number of self-referrals since the integration. On the other hand, the number of ED consults decreased;
	Urgency classification	1. The ED's urgency classifications of GP post referrals is independent from the initial classification given by the GP post itself. Therefore, it is not required to investigate the link between the urgency classifications assigned to the same patient; 2. The GP post and the ED do make use of the same triage system NTS. However, the urgency classifications are interpreted differently, which results in two different urgency classifications in practice (just like the situation investigated by Koster).
	Action selected	1. The appointment strategy for physical GP consults is adapted, based on time slots of 10 minutes. Emergency patients may enter earlier. 2. The GP post is expended with a telephonic consult conducted by a GP. 3. The physical triage activity is executed for all patients arriving at the ED, even if the GP post also conducted this activity.
	Treatment group allocation	1. The patient's entrance complaints are not used anymore to determine the patient's treatment group. The treatment group allocations will be discussed in more detail in chapter 5 *"Data analytics & simulation inputs"*. 2. The plaster requirements are not represented by a separated patient group, but the allocations will be made based on a probability matrix including the patient's treatment group and urgency classification.
	Departure type	1. The GP post departure types are based on the combination of the patient records gathered within both the GP post and the ED. 2. The ED patients' transfers and in-house deaths are classified as the departure type "Hospitalization", because both departure types do not happen frequently, but they require a considerable amount of time once they happen.
Room	Capacity	1. The ED capacity is increased by one, because the barrier room IR 15 is also used as "regular" ED treatment room.
	Type	1. The ED's two acute rooms are used for red (U0), orange (U1) and yellow (U2) patients only. The plaster rooms and fast-track rooms can be used for all types of patients, but are prioritized to patients corresponding to their dedicated function. 2. The ED's physical triage is conducted at the treatment room itself for all unlabeled patients, except for the self-referrals.
Staff	Staff allocations & roster updates	1. The GP post's physical triage is executed by a dedicated triage assistant. If no self-referrals are arriving, the assistant helps with the telephonic triage. 2. The GP assistant is also used for physical consults within the GP post. 3. The ED triage nurse takes over the physical triage of GP post self-referrals between 23:00pm and 8:00am. 4. The ED residences are based on the specialist types most frequently allocated. 5. Not all ED residences and emergency physicians are physically available at the ED all the time. Additional travel time may be required.
	Processing time	1. Travel time between the GP post and ED are excluded completely. 2. The input parameters changed for the GP post and diagnostic test activities.
Diagnostics	Type	1. The frequencies of X-rays, CT scans, ultrasound, ECG and lab research requests can be determined by comparing several patient records of all stakeholders. 2. X-ray requests made by the GP post are taken care of within the ED.
	Processing time	1. The processing times are based on the historical data of the radiology department. A probability distribution is used for this purpose. 2. The travel/waiting time required for the diagnostic employees to arrive at the ED are also based on the radiology department's patient records.
	Review	-

Table 10: Overview of the changes made into the conceptual model of Koster (2014).

Chapter 5 – Data analytics & simulation inputs

The conceptual model in Chapter 4 revealed which components of the real-world's emergency care in Enschede are included into the simulation model developments. The model's assumptions, limitations and decision flow charts made clear which type of data are required for the simulation model to run. The values of the simulation model's input variables are discussed separately within this chapter in more detail. Therefore, this chapter will continue to answer the third research question:

Research question 3: How is the out-of-hours emergency care organized within the separated GP post and ED (2014-2015) and the IEP Enschede (2016-2017)?

The patient characteristics will be discussed first, including the patient arrival distributions and the patients' characteristics. Second, the processing durations of all activities discussed in Section 4.4.2 will be analyzed in more detail. Finally, the most important results are summarized.

5.1. Patient arrivals

The type of patient inflows were described qualitatively in Section 3.2. This section will evaluate the GP post's and ED's patient arrival processes quantitatively. The theoretical background will be discussed first, including the formula required. After that, the patient arrivals per hour, day and week will be evaluated for both organizations.

5.1.1. Patient arrival formula

The Poisson distribution is one of the arrival models most commonly used in queuing systems (Law, 2007). The following three conditions should be fulfilled in order to assume that the patient arrivals are Poisson distributed:

1. Patients arrive one at a time.
2. The number of patient arrivals in any time interval is independent of earlier patient arrivals.
3. The arrival distribution is independent from the arrival event's time.

The first two conditions seems to be valid for both the GP post and ED, but the number of patient arrivals is time dependent at both the GP post and ED. Therefore, the patient arrivals are assumed to follow a Non-stationary Poisson Process, in which the patient arrival rate is time dependent.

In order to model the patient arrivals correctly, the underlying arrival rates λ are determined by analyzing historical data obtained from patient records. Patient arrivals during a national holiday are excluded from the data, because of the altered workforce planning used by both the GP post and the ED. Koster (2014) made use of three input parameters when analyzing the arrivals at the GP post and ED, inspired by Visser (2011). The same parameters are given in equation 5.1 and are used within this research for validation purposes.

Equation 5.1: IEP arrival rate

$$\lambda_{h,d,w} = \alpha_{h,d} \cdot \beta_d \cdot \gamma_w \qquad \forall h \in 0,\dots,23 \quad \forall d \in 1,\dots,7 \quad \forall w \in 1,\dots,52$$

With the following variables:

1. $\lambda_{h,d,w}$ = The number of arrivals at hour *h*, at day *d* in week *w*
2. $\alpha_{h,d}$ = The hour factor for hour h ∈ 1,…,24 at day d ∈ 1,…,7
3. β_d = Day factor for day d ∈ 1,…,7
4. Υ_w = Week factor for week w ∈ 1,…,52

However, the GP post and ED both have different patterns of patient arrivals. Therefore, equation 4.1. is split into two separate arrival equations, resulting in equation 5.2 and equation 5.3 for the GP post's and ED's arrival rates respectively.

Equation 5.2: GP arrival rate	$\lambda^{G}_{h,d,w} = \alpha^{G}_{h,d} \cdot \beta^{G}_{d} \cdot \gamma^{G}_{w}$	$\forall h \in 0,\dots,23$ $\forall d \in 1,\dots,7$ $\forall w \in 1,\dots,52$
Equation 5.3: ED arrival rate	$\lambda^{E}_{h,d,w} = \alpha^{E}_{h,d} \cdot \beta^{E}_{d} \cdot \gamma^{E}_{w}$	$\forall h \in 0,\dots,23$ $\forall d \in 1,\dots,7$ $\forall w \in 1,\dots,52$

5.1.2. Hour factor α_h

The hour factor α_h equals the average number of arrivals per hour h (equation 5.4). The hour factor can be determined by investigating the daily arrival pattern within the patient records (Koster, 2013).

Equation 5.4: hour factor	$\alpha_{h,d} = \frac{1}{t} \cdot \sum_{\forall w} \sum_{\forall y} X_{h,d,w,y}$	$\forall h \in 0,\dots,23$ $\forall d \in 1,\dots,7$

The variable $X_{h,d,w,y}$ represents the number of patient that arrived at hour $h \in 1,\dots,24$ on day $d \in 1,\dots,7$ during week $w \in 1,\dots,52$ in the year $y \in \{2014; 2015; 2016; 2017\}$. The parameter t represents the number of days $d \in 1,\dots,7$ available within the time horizon selected. Because of the national holidays, the value of the parameter t differs for every day $d \in 1,\dots,7$. The years y are divided into the separated and integrated organization of the out-of-hours emergency care. The GP post's and ED's daily arrival patterns are visualized by Figure 25 and Figure 26. Both arrival processes clearly depend on the hour of arriving, because a clear repeating pattern can be ovserved for each day. Therefore, the emperical arrival observations are required to model the arrival pattern.

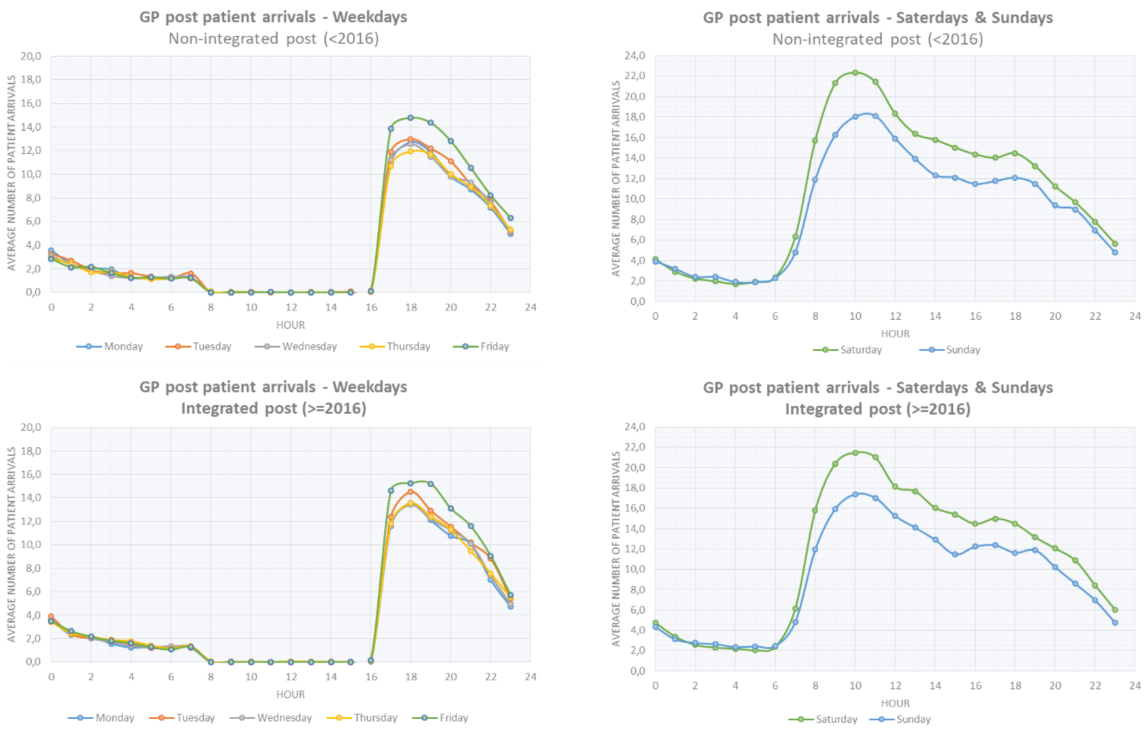


Figure 25: A visualization of the GP post's average daily patient arrivals for the period 2014-2017, including the ED's self-referrals from between 11:00pm and 8:00am. The left figures represent the GP post's patient arrivals during weekdays, while the right figures represent patient arrivals during weekends. The two top figures represent the patient arrivals before integration (2014 and 2015), while the two bottom figures represent the patient arrivals after the integration (2016-2017).

The GP post's average patient arrival patterns seem to be significantly different for weekdays and during the weekend, because the GP post is only operational from 5:00 pm until 8:00 am during weekdays and it's fully operational during the weekends. Therefore, two different sets of patient arrival patterns can be observed within the GP post:

1. Weekdays: $D_{GP\ post,\ weekdays}$ = {Monday; Tuesday; Wednesday; Thursday; Friday}
2. Weekend: $D_{GP\ post,\ weekend}$ = {Saturday; Sunday}

The patient arrival patterns in Figure 25 are roughly the same for each day within the corresponding set, the patterns also seem equal for the non-integrated (2014-2015) and the integrated emergency care organizations (2016-2017). However, the arrival rate seems to be different for various days within each set. For example, the average patient arrival rate at Friday seems to be higher in comparison with the other weekdays. The arrival pattern for Saturdays seems to be the same for Sundays, but the arrival rate at Saturday seems to be higher than Sunday for almost every hour. Therefore, a day factor should be introduced which could include the different arrival rates observed. The detailed analysis of these daily factors is given in Section 5.1.3.

The ED's average patient arrival patterns also depend on the hour of arriving and the arriving patterns are insignificantly different for weekdays and during the weekend (as identified for the GP post's arrivals). The average number of patient arrivals is higher arround noon during working days in comparison with Saturdays and Sundays. The number of patient arrivals at night is higher during the weekend. Finally, the patient arrivals at Saturday are always higher then the arrivals at Sunday, except for some small fluctuations during midnight. Therefore, two different sets of patient arrival patterns can be observed within the ED:

1. Weekdays: $D_{GP\ post,\ weekdays}$ = {Monday; Tuesday; Wednesday; Thursday; Friday}
2. Weekend: $D_{GP\ post,\ weekend}$ = {Saturday; Sunday}

Figure 26: A visualization of the GP ED's average daily patient arrivals for the period 2014-2017. Notice that the external- and self-referrals are included only. The left figures represent the ED's patient arrivals during weekdays, while the right figures represent patient arrivals during weekends. The two top figures represent the patient arrivals before integration (2014 and 2015), while the two bottom figures represent the patient arrivals after the integration (2016 and 2017).

The patient arrival patterns in Figure 26 are roughly the same for each day within the corresponding set, the patterns also seem equal for the non-integrated (2014-2015) and the integrated emergency care organizations (2016-2017). The arrival rate seems to be different for various days within each set, as observed for the GP post patient arrivals in Figure 25. A day factor should be introduced which could include the different arrival rates observed. The detailed analysis of these daily factors is given in paragraph 5.1.3.

5.1.3. Day factor β_d

The day factor β_d represents the number of daily patient arrivals in relation to the average number of patient arrivals of the corresponding week set. Therefore, the day factor can be used to distinguish relative busy and quite days from each other. The day factor is determined by dividing the total number of patient arrivals of day d by the average number of daily patient arrivals for the corresponding set of days D in the corresponding week w, as given by equation 4.5. The day factors are independently determined for all days present within the available pattern sets D ∈ {Weekdays. Weekend}, because of the different arrival patterns observed in the previous section.

Equation 4.5: day factor

$$\beta_d = \frac{\sum_{\forall h} X_{h,d,w,y}}{\frac{1}{t} \cdot \sum_{\forall h} \sum_{\forall d} X_{h,d,w,y}} \qquad \begin{array}{l} \forall d \in D \\ \forall w \in 0,\dots,52 \\ \forall y \ \in 1,\dots,4 \end{array}$$

The variable $X_{h,d,w,y}$ represents the number of patient that arrived at hour h $\in 1,\dots,24$ on day d ∈ 1,…,7 during week w ∈ $1,\dots,52$ in the year y ∈ $\{2014; 2015; 2016; 2017\}$. The parameter t represents the number of days available within one week, which is therefore equal to t=5 for weekdays and t=2 for weekends. Weeks including one or more holidays are excluded. Note that the ED arrivals only include external- and self-referred patients, the GP post referrals are not included.

Correlation tests revealed that both the GP post's and ED's day factors are independent from each other. Therefore, it is plausible to assume that the day factors' samples result from some underlying distribution. However, the significant differences between the day factors are investigated in more detail first by the application of a paired samples t-test. Appendix I provides a full description of the correlation and paired samples t-test. A probability function is fitted to the arrival data for each set of days found by the paired sample t-tests. Table 11 visualizes all the estimated probability functions resulting from the Chi squared tests applied in the simulation software *"Tecnomatix Plant Simulation"*.

Organization type	Day(s) of the week	# bins Sturges's rule	Lower bound	Upper bound	Distribution	Chi statistic	Chi value	Parameter 1	Parameter 2
Separated GP post (2014-2015)	Monday	7	0,8	∞	Lognorm	2,21	5,98	1,01	0,09
	Tuesday, Wednesday & Thursday	9	-∞	∞	Lognorm	7,36	11,06	0,96	0,10
	Friday	7	-∞	∞	Lognorm	6,70	9,48	1,13	0,11
	Saturday	7	-∞	∞	Normal	6,16	9,48	1,08	0,05
	Sunday	7	-∞	∞	Normal	6,16	9,48	0,92	0,05
Integrated GP post (2016-2017)	Monday, Tuesday, Wednesday & Thursday	9	0,7	∞	Lognorm	5,75	11,06	0,97	0,09
	Friday	7	-∞	∞	Weibull	0,69	9,48	12,11	1,16
	Saturday	7	-∞	∞	Normal	1,85	9,48	1,06	0,04
	Sunday	7	-∞	∞	Normal	1,85	9,48	0,94	0,04
Separated ED (2014-2015)	Monday & Friday	8	-∞	∞	Normal	4,56	11,06	1,06	0,10
	Tuesday	7	-∞	∞	Normal	3,03	9,48	0,93	0,09
	Wednesday & Thursday	8	-∞	∞	Normal	3,13	11,06	0,97	0,10
	Saturday & Sunday	8	-∞	∞	Lognorm	1,51	9,48	1,00	0,10
Integrated ED (2016-2017)	Monday & Friday	8	-∞	∞	Lognorm	2,74	9,48	1,05	0,10
	Tuesday & Wednesday	8	-∞	∞	Gamma	3,22	9,48	83,15	0,01
	Thursday	7	-∞	∞	Weibull	1,93	9,48	11,28	1,03
	Saturday	7	-∞	∞	Lognorm	0,38	5,98	1,04	0,09
	Sunday	7	-∞	∞	Lognorm	0,73	5,98	0,96	0,09

Table 11: Estimated probability functions underlying the GP post's and ED's daily arrival factors. These factors are determined for the separated and integrated out-of-hours emergency care organization. Two parameters are required to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ), while the "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β).

5.1.4. *Week factor Υ_w*

The week factor Υ_w represents the number of weekly patient arrivals in relation to the average number of patient arrivals of the corresponding year. Therefore, the week factor can be used to distinguish relative busy and quite weeks from each other. The week factor is determined by dividing the total number of patient arrivals of week w by the average number of daily patient arrivals in the corresponding year y, as given by equation 4.6.

Equation 4.6: week factor

$$\beta_{w,y} = \frac{\sum_{\forall h} \sum_{\forall d} X_{h,d,w,y}}{\frac{1}{t} \cdot \sum_{\forall h} \sum_{\forall d} \sum_{\forall w} X_{h,d,w,y}} \qquad \begin{array}{l} \forall w \in 0, \dots, 52 \\ \forall y \ \in 1, \dots, 4 \end{array}$$

The variable $X_{h,d,w,y}$ represents the number of patient that arrived at hour h ∈ 1,...,24 on day d ∈ 1,...,7 during week w ∈ 1,...,52 in the year y ∈ {2014. 2015. 2016. 2017}. The parameter t represents the number of weeks available within one year, which is therefore equal to t=52. The first and last week are removed for each year, because the number of days included in these weeks differ yearly. Other holidays are included in the week factor analysis in order to identify any seasonal effects.

A correlation analysis of the week factors $\beta_{w,y}$ revealed that the samples are not completely independent from each other (Appendix J) A pair of successive weeks of GP patient arrivals is moderately and positively correlated. For example, if the number of patients in week i is relatively high, than there is a moderate probability that week i+1 also faces a lot of patient arrivals. A pair of successive weeks including ED patient arrivals is less correlated, but still statistically significant.

a) GP post's week factor distribution. *b) ED's week factor distribution.*

Figure 27: The week factors' 95% confidence intervals for the GP post and the ED within the period from 2014 up to 2017.

The week factors' distributions are visualized by Figure 27. The presence of holidays result in some GP post's patient arrival peaks during the spring and during the year's last week. The GP post faces relatively more patients during the first half of the year, the number of patient arrivals drops after the summer break. The ED mainly faces a large drop of patient arrivals during the summer break.

The correlation coefficients and confidence intervals found in *Figure 27* reveal a repeating pattern, indicating a seasonal effect is present at both the GP post and the ED. However, it is still assumed that the week factor samples are independent from each other and do not follow any seasonal effect. Two main reasons are provided for this simplification:

1. The week factors' fluctuations itself are relatively small per week. A clear seasonal effect is obtained, but the changes per week are not significant. On average, the same results can be obtained by assuming a week factor follows a fitted distribution;
2. The GP post's and ED's staff rosters are adjusted to seasonal effects observed in real life, while the conceptual model includes a static staff roster only.

Table 12 provides an overview of the probability functions underlying the empirical week factor samples. A more detailed analysis of the week factors is represented in Appendix J.

Organization type	# bins Sturges's rule	Lower bound	Upper bound	Distribution	Chi statistic	Chi value	Parameter 1	Parameter 2
Separated GP post (2014-2015)	7	-∞	∞	Lognorm	6,21	9,48	1,00	0,08
Integrated GP post (2016-2017)	7	-∞	∞	Normal	1,36	9,48	1,00	0,08
Separated ED (2014-2015)	7	-∞	∞	Normal	5,61	9,48	1,02	0,07
Integrated ED (2016-2017)	7	-∞	∞	Normal	1,22	9,48	1,01	0,07

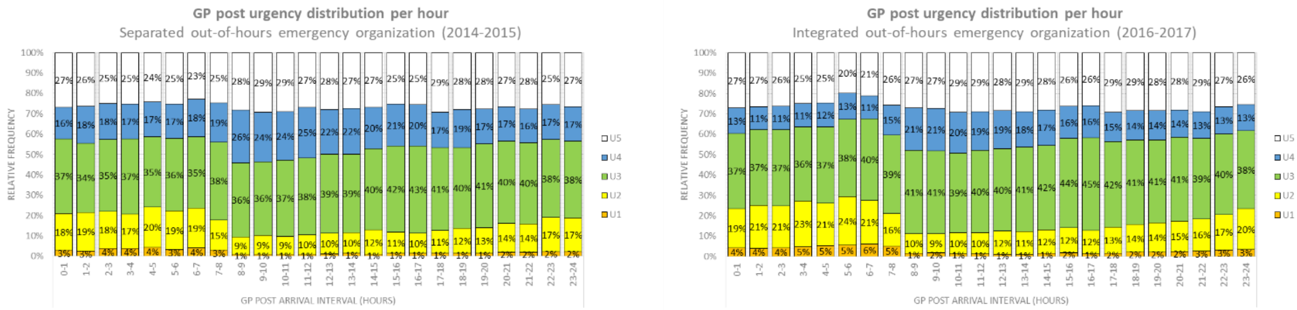
Table 12: Estimated probability functions underlying the GP post's and ED's weekly arrival factors. These factors are determined for the separated and integrated out-of-hours emergency care organization. Only two parameters are required to describe the "normal" and "lognormal" distribution, the mean (μ) and standard deviation (σ).

5.2. GP post patient characteristics

The decision flow diagram in Section 4.7 indicated that the GP post's urgency classifications are allocated first to all arriving patients. Second, the allocation of the patients' care pathways will be discussed, including the corresponding staff allocations.

5.2.1. Urgency classifications

The GP post's urgency classification depends on the patient's arrival hour (Figure 28). The number of high urgency patients (U1 or U2) is relatively high during the night in comparison with arrivals between 8:00am and 5:00pm. Over the years, the proportion of non-urgent patients (U4) decreased relatively for the night and office hours, while these patients are nowadays arriving relatively more often during the evening. The GP post's urgency classifications do also not depend on the patient's arrival day.

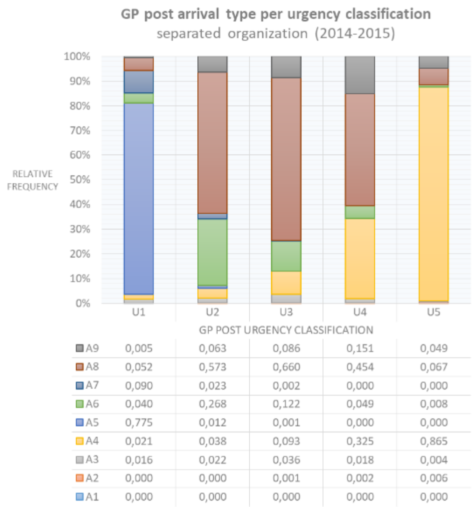


a) Separated emergency care organization (2014-2015) *b) Integrated emergency care organization (2016-2017)*

Figure 28: The urgency classifications allocated to the patients arriving at the GP post per hour.

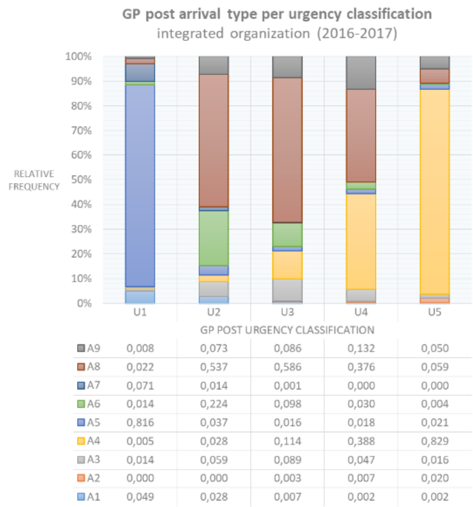
5.2.2. Entrance GP post (path A)

The selection of the patient's A-path depends on the urgency classification given earlier. Figure 29a and Figure 29b visualize the A-path distributions for both the separated and integrated emergency care organizations respectively. The relative frequencies remained quite the same since the integration of the two organizations. However, the relative proportion of physical GP consults (A8) decreased for all urgency classifications. Second, the number of emergent self-referrals increased for all urgency classifications, especially for the U1 and U2 patients that are seen by the ED triage nurse during the night. Thirdly, the relative proportion of telephonic advice given by the GP assistant increased for the U3 and U4 patients. Finally, more telephonic GP consults are scheduled for all urgency classifications.



	U1	U2	U3	U4	U5
A9	0,005	0,063	0,086	0,151	0,049
A8	0,052	0,573	0,660	0,454	0,067
A7	0,090	0,023	0,002	0,000	0,000
A6	0,040	0,268	0,122	0,049	0,008
A5	0,775	0,012	0,001	0,000	0,000
A4	0,021	0,038	0,093	0,325	0,865
A3	0,016	0,022	0,036	0,018	0,004
A2	0,000	0,000	0,001	0,002	0,006
A1	0,000	0,000	0,000	0,000	0,000

a) Separated out-of-hours emergency organization (2014-2015)



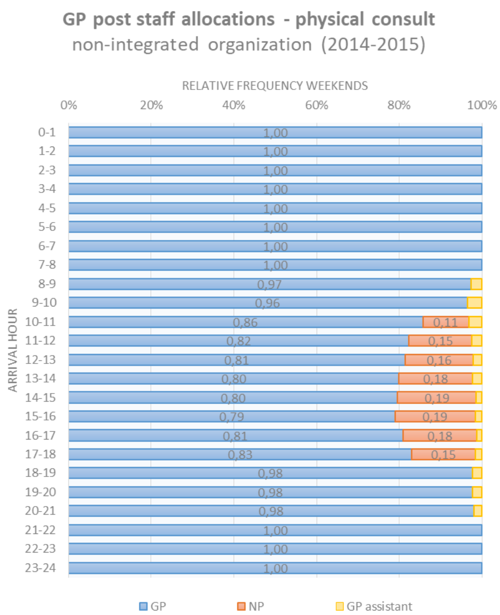
	U1	U2	U3	U4	U5
A9	0,008	0,073	0,086	0,132	0,050
A8	0,022	0,537	0,586	0,376	0,059
A7	0,071	0,014	0,001	0,000	0,000
A6	0,014	0,224	0,098	0,030	0,004
A5	0,816	0,037	0,016	0,018	0,021
A4	0,005	0,028	0,114	0,388	0,829
A3	0,014	0,059	0,089	0,047	0,016
A2	0,000	0,000	0,003	0,007	0,020
A1	0,049	0,028	0,007	0,002	0,002

b) Integrated out-of-hours emergency organization (2016-2017)

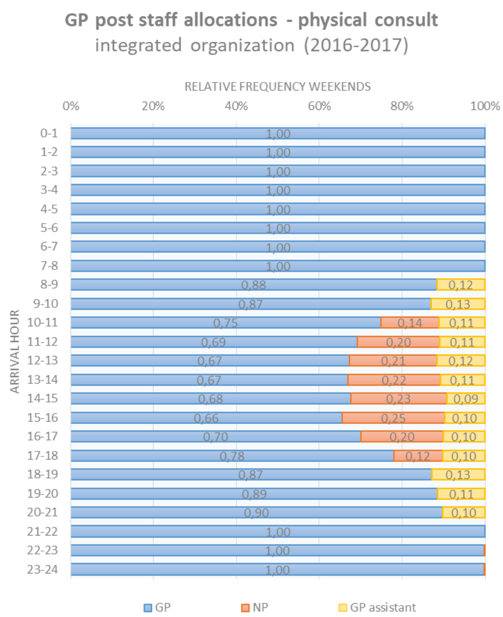
Figure 29: The distribution of the care pathways into the GP post for both the separated and integrated out-of-hours emergency care, including the ED self-referrals. The A-path ratios are determined for each urgency classification separately.

5.2.3. GP post physical consult

The GP assistant and the NP are only available during the weekend for both during the separated (2014-2015) and the integrated (2016-2017) emergency care in Enschede. Sometimes the GP assistant can perform small treatments during working days, but the frequencies of these consults are negligible. During the weekends, the relative frequencies of the staff allocations depend on both the type of patient arrivals and the staff rosters. Therefore, the staff allocations are determined for each hour interval separately (Figure 30). The total number of patients invited to the GP post for a physical consult slightly increased since the integration of the GP post and the ED. However, the GP is relatively less often allocated to these physical consults, while the GP assistant and NP are allocated more often.



a) Separated out-of-hours emergency organization (2014-2015)

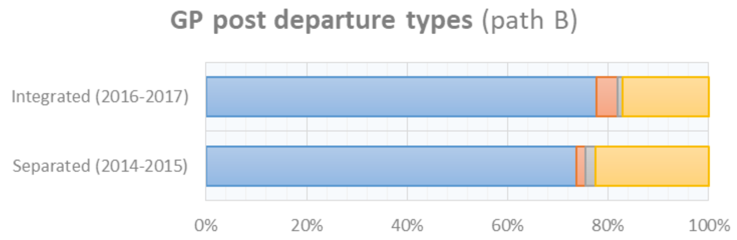


b) Integrated out-of-hours emergency organization (2016-2017)

Figure 30: The distribution of the GP post's staff allocations to the physical consults scheduled for both the separated and integrated emergency care in Enschede. The relative frequencies are given for each hour interval separately, the values only apply to weekends.

5.2.4. GP post departure types (path B)

The GP post's departure types were already discussed in Section 3.2.3. The relative departure types are given in Figure 31. The total number of patients visiting the GP post physically remained approximately the same for the separated and integrated emergency organization in Enschede. The relative frequency of the patients referred to the ED decreased over the years, while more patients are referred to the X-ray department instead. It is remarkable that the number of B2 patients increased, which indicates that the number of diagnostic test requests increased in case of doubt.



	Separated (2014-2015)	Integrated (2016-2017)
Go home directly	30974	32878
Via X-ray to home	761	1782
Via X-ray to ED	789	381
Referred to ED	9494	7283

Figure 31: The absolute and relative frequencies of the GP post's departure types during the separated and integrated out-of-hours emergency organization in Enschede.

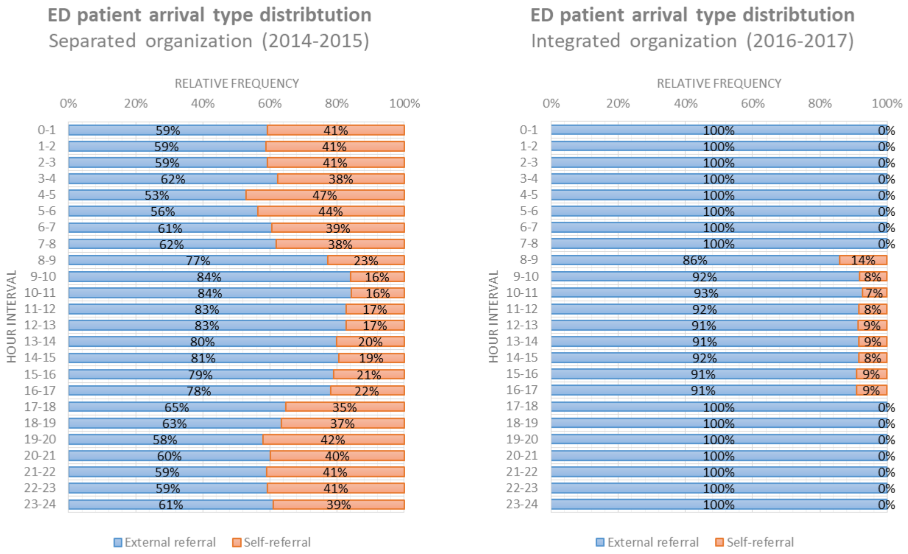
5.3. ED patient characteristics

The decision flow diagram in Section 4.7. *"Creating patients"* indicated that all ED patients' characteristics depend on their arrival type first. Secondly, the patient's treatment groups and care pathways will be discussed, including the corresponding staff allocations and diagnostic test requests. Finally, the ED patient's urgency classification is determined to allocate the departure type and need for a medical specialist. The input parameters to each variable will be discussed in the following subparagraphs. Most data inputs are separately visualized for the ED's three types of patient arrivals: 1) external referrals; 2) self-referrals and 3) GP post referrals. In this chapter, only the visualizations corresponding to the external referrals are provided, all other graphs are included in Appendix K.

5.3.1. ED arrival types

The patients' characteristics depend mostly on how the patient is referred to the ED. Therefore, these type of patient arrivals are allocated to the patient first. Second, the labeled or unlabeled classification is applied in order to determine the allocation of an emergency physician or resident respectively, all other ED characteristics are allocated after that. Most patient are referred to the ED by an external organization, with 38.5% unlabeled patients, both before and after the integration (Section 3.2.2). The GP post referrals include just 26.3% and 30.6% unlabeled patients for the separated and integrated organization respectively. The smallest group, self-referrals", consists of unlabeled patients only by definition.

Note that the ED patient arrival factors discussed in paragraph do not include the GP post referrals, because these patients are already included into the GP post's arrival rates. Therefore, the arrival types per hour interval are determined for the ED self-referrals and external referrals only (Figure 32). Before the integration of the GP post and the ED, the number of self-referrals decreased relatively during office hours, mainly because the number of external referrals increased absolutely by day. Due to the integration, no self-referrals arrive at the ED in between 5:00pm and 8:00am the next day. The relative proportion of self-referrals dropped significantly.



a) Separated organization (2014-2015) *b) Integrated organization (2016-2017)*

Figure 32: ED patient arrival distributions, excluding the GP post referrals.

5.3.2. ED treatment groups

The patient's care pathway depends on the entrance complaints given during the physical triage. For example, bone fractures would require X-rays, while pain on the chest would probably require examination of the pulmonary resident. Three classification techniques are applied in order to select the specialist types required based on the NTS triage results, see Appendix L. If all entrance complaints are included into the classification analysis, an accuracy level of 77% could be obtained, this accuracy level is considered to be too low for proper resource allocations. Therefore, the empirical distributions of the available specialist types are used only to define the patients' alternative care pathways, resulting in the six treatment groups consisting of the most frequently allocated specialist types.

The treatment groups differ significantly for each type of patient arrival, an example is given in Figure 33 for the external referrals. The treatment group distributions are approximately the same for each day before and after the integration of the GP post and ED. A more detailed analysis of all treatment group allocations is given in Appendix K.

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Figure 33: The average ED treatment groups' distributions per hour interval. Small frequency labels are not included.

5.3.3. Diagnostic test requests.

The type and number of diagnostic test requests depend on the patient's specialist type allocated. The radiology department's patient records are gathered and analyzed in order to determine which type and how many diagnostic test requests are originating from the ED, separated per treatment group. Appendix M "Diagnostic test requests" provides a full overview of the data analytics conducted. The laboratory and ECG data did not became available for this research unfortunately, the input values of these two diagnostic tests are based on the assumptions made by Koster (2014).

Table 13 and Table 14 represent the probability and duration of the diagnostic test requests originating from the radiology department during the separated and integrated emergency care organization respectively. Two ratios are developed to differentiate between the waiting times and activities' durations for each treatment group.

Diagnostic test	Input values	Treatment groups - separated organization (2015)						
		Surgery	Internal medicine	Pulmonary medicine	Neurology	Orthopedics	Gastro & liver	Other
X-ray	Probability	14%	13%	23%	8%	20%	8%	4%
	Activity ratio	0,95	1,22	1,01	1,00	1,05	1,02	0,73
	Travel ratio	1,01	0,91	1,00	1,20	0,97	1,07	0,82
CT-scan	Probability	13%	2%	13%	100%	11%	3%	6%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,05	1,15	1,23	0,93	1,06	0,93	0,99
Ultrasound	Probability	10%	8%	1%	0%	4%	14%	5%
	Activity ratio	0,98	1,06	0,88	0,11	0,53	1,54	0,37
	Travel ratio	0,94	1,24	0,73	0,00	1,13	0,81	1,68
Laboratory	Probability	33%	100%	100%	100%	33%	100%	50%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
ECG	Probability	10%	50%	75%	75%	10%	50%	25%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00

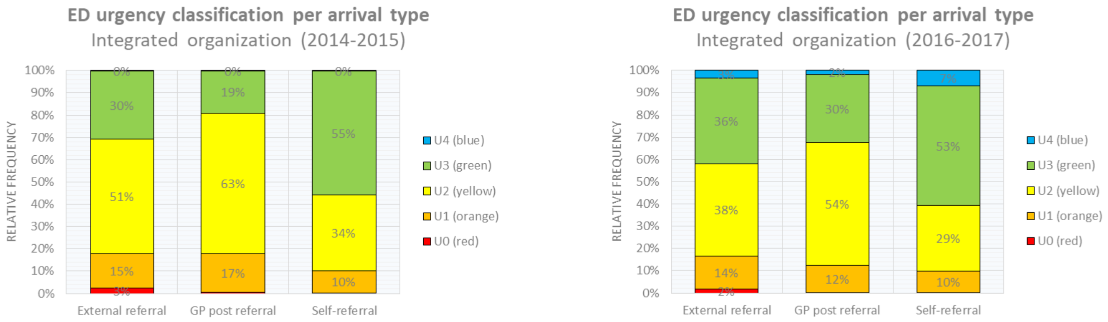
Table 13: The probability and duration ratios for the activity and travel durations of all diagnostic tests per treatment group during the separated emergency care (2014-2015). The ratios will be used to modify the distributions shape factors.

Diagnostic test	Input values	Treatment group - integraged organization (2016-2017)						
		Surgery	Internal medicine	Pulmonary medicine	Neurology	Orthopedics	Gastro & liver	Other
X-ray	Probability	47%	43%	77%	17%	65%	18%	9%
	Activity ratio	1,10	0,91	0,84	0,92	1,00	0,85	0,82
	Travel ratio	1,03	0,95	0,95	1,02	1,00	0,99	0,96
CT-scan	Probability	14%	3%	12%	98%	13%	2%	3%
	Activity ratio	1,10	1,11	1,10	0,91	0,92	1,47	1,12
	Travel ratio	1,09	1,24	1,10	0,91	1,01	1,21	0,99
Ultrasound	Probability	12%	6%	1%	0%	5%	7%	1%
	Activity ratio	1,01	0,96	0,82	0,66	0,92	1,06	0,80
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Laboratory	Probability	33%	100%	100%	100%	33%	100%	50%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
ECG	Probability	10%	50%	75%	75%	10%	50%	25%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Table 14: The probability and duration ratios for the activity and travel durations of all diagnostic tests per treatment group during the integrated emergency care (2016-2017). The ratios will be used to modify the distributions shape factors.

5.3.4. ED urgency classifications

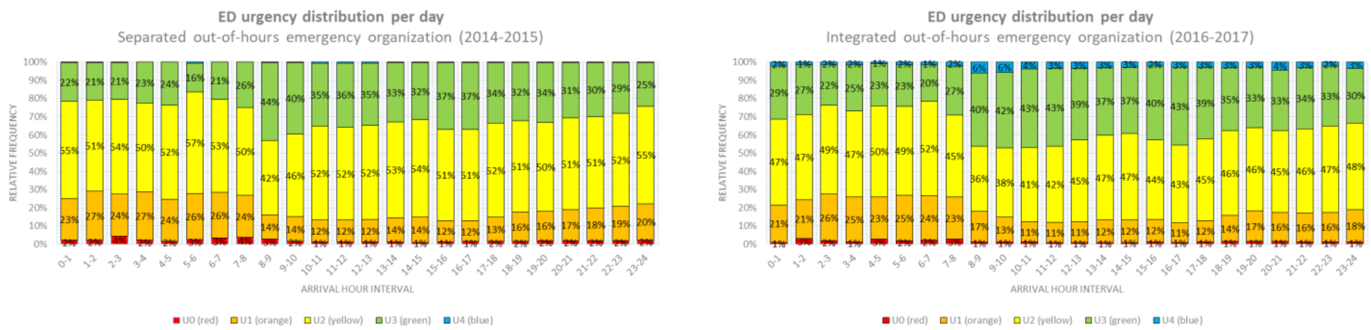
The patient's urgency classification strongly depends on the treatment group allocated, while the treatment groups are dependent on the patient's arrival type. Therefore, the ED urgency classifications are determined per treatment group for all three arrival types. The comparisons are interesting, because the MTS decision support system was used during the research of Koster (2012-2013) and during the separated organization in 2014 and 2015, while the NTS decision support system is used since the 11th of January 2016. It can be concluded that more patients are classified as less urgent (U3 or U4) for all arrival types since the usage of NTS (Figure 34).



a) Separated organization (2014-2015) *b) Integrated organization (2016-2017)*

Figure 34: ED urgency classifications per arrival type for both the separated and integrated out-of-hours emergency care.

The ED patient arrivals differ per hour interval (Figure 35). The GP post's urgency classifications do also not depend on the patient's arrival day. The urgency distributions differs significantly for each treatment group, which is mainly explained by the different staff allocations made per hour (Figure 33). However, the differences are the same for all ED arrival types, a full analysis of the urgency distributions is given in Appendix K.



a) Separated emergency care organization (2014-2015) *b) Integrated emergency care organization (2016-2017)*

Figure 35: The urgency classifications allocated to the patients arriving at the ED per hour.

5.3.5. Medical specialist request

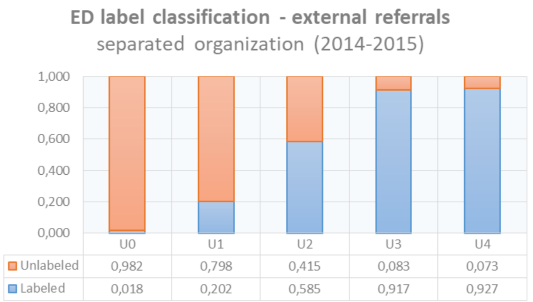
The treatment groups' residents and emergency physicians are able to contact a medical specialist for diagnostic and treatment related questions. It is even possible that the medical specialist itself visits the ED in order to support the patient's treatment physically. The probability of requesting a medical specialist is assumed to depend on the patient's urgency classification (Koster, 2014). The ED patient records do not include any data regarding these support activities. Therefore, the assumptions made by Koster are evaluated, checked and reused (Table 15). The probabilities and waiting times are not impacted by the decision to integrate the GP post and the ED.

ED urgency level	Probability	Travel/waiting time
U0 (red)	98%	5 minutes
U1 (orange)	50%	15 minutes
U2 (yellow)	15%	60 minutes
U3 (green)	5%	120 minutes
U4 (blue)	0%	120 minutes

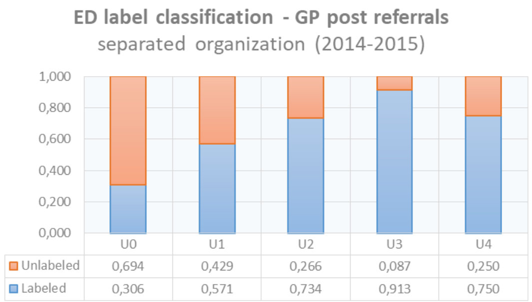
Table 15: The probability of calling a medical specialist per ED urgency classification.

5.3.6. ED patient label

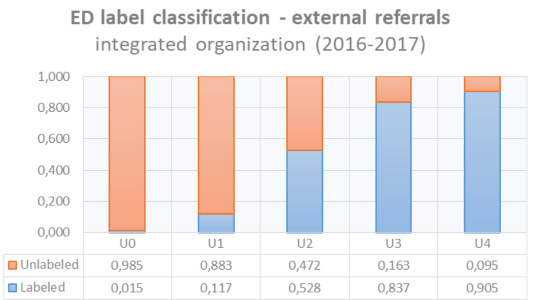
The ED patients receive a label to determine the required staff allocation, as described in Section 5.3.1. Labeled patients are referred to the ED by some medical stakeholder, while unlabeled arrive unannounced or by ambulance or trauma helicopter. Therefore, the label classification depends strongly on the patient's urgency classification, for example, a trauma helicopter is used for high urgent patients only. The label classifications for external and GP post referrals are visualized in Figure 36.



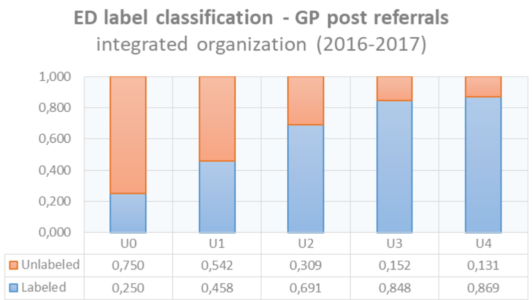
a) External referrals separated organization (2014-2015)



b) GP post referrals separated organization (2014-2015)



c) External referrals integrated organization (2016-2017)



d) GP post referrals integrated organization (2016-2017)

Figure 36: Label classifications assigned to the ED patients. The self-referrals are excluded, because these patients are classified as unlabeled patients by definition.

5.3.7. ED plaster request

The plaster requirements depend on the patient's treatment group and urgency classification allocated. The orthopedics and surgery specialists are responsible for the plaster activity, which means that these treatment groups includes relative more patients that require plaster (Table 16). The frequencies in Table 16 are gathered from the patient records, a plaster is required if the patient made a follow-up appointment at the plaster department in the MST hospital.

Speciaslist type	Separated organization (2014-2015)					Integrated organization (2016-2017)				
	U0	U1	U2	U3	U4	U0	U1	U2	U3	U4
Surgery	0,00	0,01	0,08	0,40	0,40	0,00	0,02	0,06	0,46	0,27
Internal medicine	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Neurology	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Orthopedics	0,00	0,02	0,14	0,54	0,50	0,00	0,01	0,10	0,74	0,59
Pulmonary medicine	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Gastrointestinal & liver	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Other	0,00	0,00	0,00	0,01	0,10	0,00	0,00	0,00	0,01	0,04

Table 16: The probability that a patient requires plaster, which depends on the patient's treatment group and urgency classification allocated. The frequencies are determined for the separated and integrated emergency organization.

5.3.8. ED departure types (path C)

The ED departure type depends on the patient's urgency classification given by the ED. The number of patient's going home directly decreased for all urgency levels since the integration of the GP post and the ED (Table 17), which indicates that more patients are admitted into the hospital since the integration of the GP post and the ED.

Separated organization (2014-2015)						
GP post arrival	ED departure type	ED URGENCY CLASSIFICATION				
		U0	U1	U2	U3	U4
C1	Home	0,027	0,210	0,451	0,863	0,881
C2	Hospitalization	0,973	0,790	0,549	0,137	0,119

a) Separated emergency organization (2014-2015).

Integrated organization (2016-2017)						
ID	ED departure type	ED URGENCY CLASSIFICATION				
		U0	U1	U2	U3	U4
C1	Home	0,005	0,183	0,360	0,737	0,830
C2	Hospitalization	0,995	0,817	0,640	0,263	0,170

b) Integrated emergency organization (2016-2017).

Table 17: Relative frequencies of the ED's departure types separated per urgency classification (Path C).

5.4. Processing times

An empirical distribution can be found for all essential activity durations within the GP post and the ED. However, it would be easier to describe the activities' durations by a few parameters instead of a large number of individual patient records. Therefore, a theoretical probability distribution is searched for each core activity. Five theoretical probability distributions are investigated for this purpose: 1) the normal distribution. 2) the lognormal distribution. 3) the weibull distribution. 4) the gamma distribution and 5) the exponential distribution. The Sturges' rule is used in order to determine the number of histogram's intervals, while the chi-square test is used to compare the duration's histogram with the fitted density function. Appendix N visualizes the chi-square test results in more detail.

5.4.1. GP post processing times

The GP post's processing times are automatically stored within the administration system "Topicus". For each activity, the start and end time are stored in order to calculate the activity's duration for each patient individually. The hypothesized distribution that best describe the duration of the GP post's core activities represented in Table 18 and Table 19. The triage activities are also included within the probability fitting procedure in order to describe the patient admittance processes adequately. The driving durations required for a GP visit are also included.

Separated organization (2014-2015)						
GP post activity	**Distribution**	**Parameter 1**	**Parameter 2**	**μ**	**Min**	**Max**
Telephonic triage	Lognormal	**CONFIDENTIAL**				
Physical triage	Lognormal					
GP physical consult	Lognormal					
GP visit	Gamma					
GP driving duration	Lognormal					
GP telephonic consult	Lognormal					
NP consult	Gamma					
GP assistant consult	Normal					

Table 18: The hypothesized probability function that best describes the duration of the GP post's core activities during the separated out-of-hours emergency care organization (minutes). Two parameters are required in order to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ). The "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β).

Integrated organization (2016-2017)						
GP post activity	**Distribution**	**Parameter 1**	**Parameter 2**	**μ**	**Min**	**Max**
Telephonic triage	Gamma	**CONFIDENTIAL**				
Physical triage	Weibull					
GP physical consult	Gamma					
GP visit	Gamma					
GP driving duration	Lognormal					
GP telephonic consult	Lognormal					
NP consult	Gamma					
GP assistant consult	Lognormal					

Table 19: The hypothesized probability function that best describes the duration of the GP post's core activities during the integrated out-of-hours emergency care organization (minutes). Two parameters are required in order to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ). The "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β).

5.4.2. ED processing times

The ED patient records only include three reliable time registrations: 1) the time of the patient's arrival. 2) the time of initiating the triage activity and 3) the time of the patient's departure. Therefore, it is impossible to analyze the ED's individual activity durations in the same way as done for the GP post. Assumptions should be made for the activities' durations, based on the assumptions previously made by Koster (2014) and expert opinions (Table 22). Only the activities performed by the radiology department can be analyzed in more detail (Table 20 and Table 21). A more extensive analysis of the diagnostic travel and activity durations is given in Appendix N.

ED activity	Distribution	Parameter 1	Parameter 2	µ	Min	Max
	Separated organization (2014-2015)					
CT scan waiting	Gamma					
CT scan duration	Exponential					
Ultrasound waiting	Weibull	CONFIDENTIAL				
Ultrasound duration	Normal					
X-ray waiting	Gamma					
X-ray duration	Exponential					

Table 20: The hypothesized probability function that best describes the duration of the ED's core activities (minutes). Two parameters are required in order to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ). The "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β), while the "exponential" distribution requires one parameter only, the arrival intensity (λ).

ED activity	Distribution	Parameter 1	Parameter 2	µ	Min	Max
	Integrated organization (2016-2017)					
CT scan waiting	Gamma					
CT scan duration	Lognormal					
Ultrasound waiting	Weibull	CONFIDENTIAL				
Ultrasound duration	Weibull					
X-ray waiting	Weibull					
X-ray duration	Weibull					

Table 21: The hypothesized probability function that best describes the duration of the ED's core activities (minutes). Two parameters are required in order to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ). The "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β), while the "exponential" distribution requires one parameter only, the arrival intensity (λ).

It is unfortunate that no intermediate time registrations are available within the ED. This prevents the direct comparison between the simulated and actual durations. However, the patients' total cycle times are included within the ED patient records, which makes it possible to validate the sum of all activities' durations. This validation process is discussed in chapter 6 and chapter 7.

ED activity	Distribution	Parameter 1	Parameter 2	µ	Min	Max
	Duration assumptions (2014-2017)					
Anamnesis ED nurse	Normal					
Anamnesis resident or emergency physician	Normal					
Plaster	Normal					
Surgery resident	Normal					
Surgery specialist	Normal					
Internal resident	Normal					
Internal specialist	Normal					
Neurology resident	Deterministic					
Neurology specialist	Normal					
Orthopedics resident	Normal					
Orthopedics specialist	Normal					
Pulmonary resident	Normal	CONFIDENTIAL				
Pulmonary specialist	Normal					
Gastrointestinal resident	Normal					
Gastrointestinal specialist	Normal					
Other resident	Normal					
Other specialist	Normal					
Lab research	Deterministic					
ECG	Normal					
Review lab research	Deterministic					
Review ultrasound	Deterministic					
Review X-ray	Deterministic					
Review CT-scan	Deterministic					
Waiting time lab research	Normal					
Waiting time ECG	Deterministic					

Table 22: The ED's activity assumptions, based on the values initiated by Koster (2014).

5.5. Staff & room allocations

Section 3.4 revealed which he staff allocations are required for each activity within both the GP post and the ED, while the staff rosters are visualized in Appendix F. A combination of these two information sources will make it possible to determine the staff allocations into the simulation model.

5.5.1. Physical triage staff allocations

The GP post is responsible for the physical triage of all out-of-hours self-referrals. One of the GP assistants is available for the physical triage of these patients once the GP post is opened. If no self-referrals are waiting for triage, this GP assistant can be used for the telephonic triage as well. However, the physical triage of self-referrals is executed by the ED triage nurses during the night. Therefore, one GP assistant shift in between 5:00pm and 11:00pm is replaced by a GP post's triage assistant, which requires a small adaptation of the rosters represented in Appendix F. The same type of modification is made for the ED nurses in between 11:00pm and 8:00am. This modification is applied to all days, both weekdays and weekends.

5.5.2. GP post physical consult

Two GPs are available for a GP post consult in between 5:00pm and 8:00am every day. During the weekend, four GPs are available between 8:00am and 5:00pm. During the weekend, a circulating GP assistant and a NP are available to conduct physical GP post consults. Section 5.2.3 discussed the staff allocation frequencies already.

5.5.3. ED treatment group staff allocations

Each treatment group discussed in paragraph 5.3.2 is helped by another type of resident. Normally, each patient should be treated by a resident corresponding to the hospital's treatment department that will most likely help the patient. However, due to commonalities within the patient's entrance complaints seen by each specialist type, some treatment groups can be treated by more types of specialties. For example, a bone fracture could be treated by a surgeon or an orthopedics resident. Therefore, these two specialist types can be clustered into one resident type. The staff allocations are given in Table 23, notice that the emergency physician can unlabeled patients only. If there is no emergency physician available, the resident type 1 takes over the care of all unlabeled patients.

		ED treatment group						
Resident type	**Arrival type**	Surgery	Internal medicine	Neurology	Orthopedics	Pulmonary	Gastro & liver	Other
Emergency physician	Unlabeled	X	X	X	X	X	X	X
Resident 1	Labeled	X			X			X
Resident 2	Labeled		X				X	X
Resident 3	Labeled			X				
Resident 4	Labeled					X		

Table 23: An overview of the staff allocations to each type of ED treatment group. The staff allocations apply for both the separated (2014-2015) and the integrated (2016-2017) emergency care organization in Enschede.

The emergency physician is only allocated to the treatment of unlabeled patients only. The probability exists that a new resident is allocated once the anamnesis is conducted by the emergency physician. This probability is based on historical data from the ED's patient records. The relative frequencies are given in Table 24.The surgery and orthopedics residents (type 1) take over the care of unlabeled patients once the emergency physician is absent.

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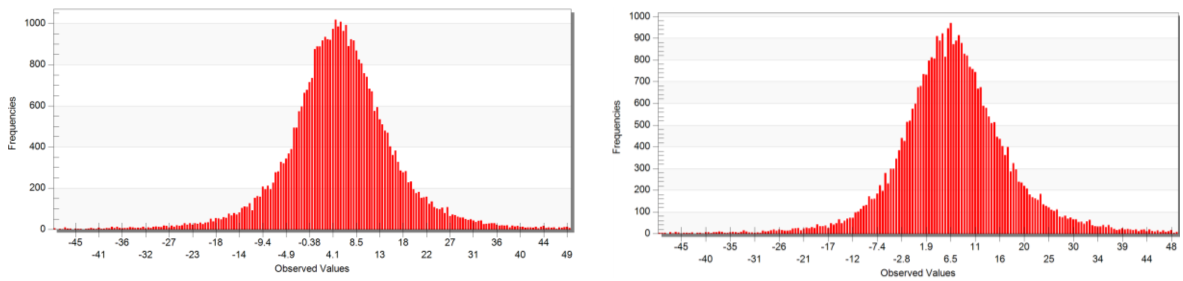
Table 24: Relative frequencies of probability that the care of an unlabeled patient is transferred from the emergency physician to the corresponding resident for both the separated (2014-2015) and the integrated (2016-2017) emergency care.

5.5.4. ED staff availability

The staff rosters in Appendix F indicate that all residents are available at each time of the day. The emergency physician is never available during the night, all other residents are expected to be available for an ED consult. However, the pulmonary and neurology resident are not always physically present at the ED itself. For example, the pulmonary resident is only available at the ED between 8:00am and 8:00pm at workday or between 11:00am and 11:00pm during weekends. If the pulmonary resident is required but not physically present at the ED, an additional travel time 30 minutes is assumed. The same applies for the neurology resident, who will require an additional travel time of 5 minutes. These 'external' residents will wait 30 minutes at the ED before returning to their own department.

5.6. Validation data modifications

Multiple simulation runs are made in order to validate the new simulation model (Chapter 6). Several adjustments to the conceptual model were required in order to align the actual and simulated input/output variables. The GP post's LOS simulated was too low after the first validation run, approximately 20% less for all five NTS urgency classifications. Therefore, two conceptual model adjustments were made in order to increase the GP post LOS. First of all, it was assumed that all patients invited for a physical GP post consult arrived at their appointment time exactly, but this is not the case in real-life. Some patients arrive early at the GP post while other patients arrive too late, as visualized in Figure 37. Therefore, a probability distribution is fitted for the difference between the patient's arrival time at the GP post and the appointment time allocated (Table 25). The patient may arrive earlier at the GP post, which will result into an increase of the patient's LOS. On average, the GP post's LOS will increase.



a) Separated organization (2014-2015) *b) Integrated organization (2016-2017)*

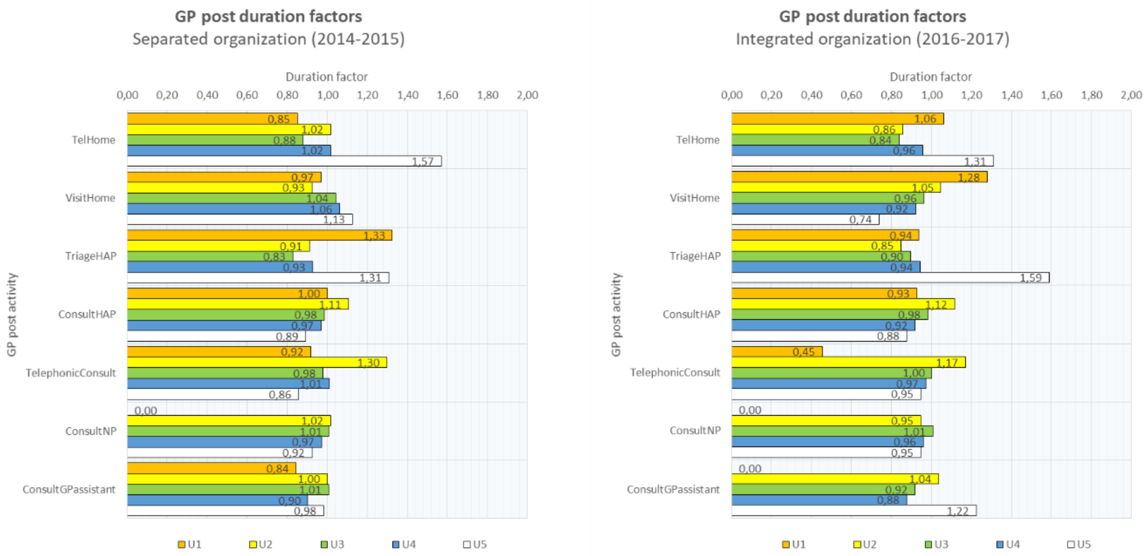
Figure 37: Distribution of the GP post patients' arrival times before or after their corresponding appointment time

Integrated organization (2016-2017)

Year	GP post activity	Distribution	Parameter 1	Parameter 2	µ	Min	Max
Separated organization (2014-2015)	Patient travel time	Normal	µ = 5.20	σ = 10.50	6.77	-100	100
Integrated organization (2016-2017)	Patient travel time	Normal	µ = 6.77	σ = 10.76	6.77	-100	100

Table 25: The hypothesized probability function that best describes the duration of the GP post patients' arrival before or after their corresponding appointment time.

Second, it was assumed that the GP post activity durations only depend on the patient's care pathway allocated. This assumption is fine in order to obtain valid average results, but it results into wrong calculations for each urgency classification separately. Therefore, all GP post activity durations are multiplied by a factor that represents the duration's deviation from the overall average for all urgency classifications. This factor indicates the difference between the average duration for the activity's corresponding urgency classification and the overall activity's duration. The resulting factors are visualized in Figure 38 for the separated (2014-2015) and integrated (2016-2017) emergency care.



a) Patient record's LOS GP post entrance (2014-2015) *b) Patient records' LOS GP post entrance (2016-2017)*

Figure 38: The GP post factor developed to differentiate between the activities' durations for all five NTS urgency classes.

The ED LOS was pretty accurate on average for both the separated and integrated emergency care organization. However, the average LOS values for each urgency classification did not match the actual results obtained from the patient records. Therefore, a new factor is implemented in order differentiate the patient's ED LOS corresponding to its urgency classification allocated (Table 26). The factors are calculated in order to match the overall average results in order to maintain the simulation model valid.

Code	Color	Separated factor	Integrated factor
U0	Red	0.95	0.70
U1	Orange	1.25	1.20
U2	Yellow	1.10	1.15
U3	Green	0.50	0.75
U4	Blue	0.15	0.15

Table 26: ED LOS factors in order to differentiate the durations for each urgency classification.

5.7. Remaining assumptions

A large proportion of the variables have their values based on the historical data gathered by the GP post, ED and radiology departments. However, the absence of detailed time registrations within the ED make it impossible to determine the exact durations for the individual steps within the patient's treatment. Therefore, assumptions are still required in order to make the model work. The following assumptions are still made today:

1. The patient arrivals are assumed to be Poisson distributed, implying that the sample's mean and standard deviation are equal to each other;
2. All patients invited for a physical consult arrive at the GP post exactly on their appointment time, without any stochastic behavior;
3. The laboratory and ECG diagnostic test requests are based on experts opinions, resulting into assumptions made for:
    a. The probability for the test's applicability per treatment group;
    b. The number of diagnostic tests requested per patient;
    c. The distributions underlying the activities' and waiting times' durations.
4. The activity durations of all ED's staff members, especially for the residents, emergency physicians and medical specialists within the ED are based on expert opinions only;
5. The probability that a medical specialist is called for support;
6. The travel times of external staff members to the GP post or ED:
    a. The travel duration of ambulances or trauma helicopters;
    b. The travel durations of external staff members.
7. Residents that are referred to the ED from an external department will wait 30 minutes before leaving the ED again.

5.8. Data analytics conclusions

The data analytics in this chapter provide insights into the differences between expectations and actual organization of the processes and patient flows within the IEP Enschede. The conceptual model in Chapter 4 revealed which components of the real-world's emergency care in Enschede are included into the simulation model developments. The model's assumptions, limitations and decision flow charts made clear which type of data are required for the simulation model to run. The values of the simulation model's input variables are discussed separately within this chapter, the most important conclusions are aggregated in Appendix O.

Chapter 6 – The simulation model

The development of a conceptual model and the data analytics allowed the creation of a simulation model in the software package “Technomatix Plant Simulation”. This chapter will be used to provide insight into the simulation model developments that have taken place. The simulation mode itself will be discussed first, while the modification to the original model developed by Koster (2014) are explained secondly. Thirdly, it is verified if the conceptual model is correctly translated. Finally, the resulting simulation model should be validated by comparing the simulation model’s results with the actual results observed in the patient records’ from both the GP post and ED. Therefore, this chapter provides an answer to research question 5 regarding the simulation model’s modifications required. However, the main aim of this chapter is to provide the reader with sufficient information in order to answer the sixth research question, because the LOS values obtained from the patient records are compared to the simulated LOS values by the new and updated simulation model.

Research question 5: Which modifications are required in order to make Koster’s simulation model up-to-date to the new conceptual model?

Research question 6: How do the performances differ for both the separated and integrated emergency care organization in Enschede from 2012 up to 2017?

Note that the sixth research question will not be fully discussed, only two of the six sub-questions will be answered in this chapter for validation purposes only:

a. What are the actual and simulated performances of the separated emergency care based on the data gathered by Koot (2018) in between 2014 and 2015?
b. What are the actual and simulated performances of the integrated emergency care based on the data gathered by Koot (2018) in between 2016 and 2017?

A full analysis of the separated and integrated emergency care performances is given in chapter 7.

6.1. Model explanation

The simulation model developed by Koster (2014) was based on a generalized and flexible framework for discrete-event simulation modeling of (integrated) emergency departments developed by Bruens & Mes (2012). This type of simulation models evolve over time by a representation in which variables’ values change at separate points in time instantaneously (Law, 2016). All decision logic is implemented into the software package “Technomatix Plant Simulation”, a software package for integrated, graphic an object-oriented modelling, simulation and animation (Mes, 2016). The user can quickly develop a simulation model by dragging predefined components like processing stages, table files or variables into a “canvas” environment. The processes are simulated by the decision logic programmed by the user itself.

Bruens & Mes (2012) defined three main components for the discrete-event simulation model development, which also represent the patient, resources and decision logic:

1. **Moving entities**, which mainly represent the patients requesting emergency care;
2. **Recourses**, the conceptual model included a few sets of essential resources in order to treat the patient adequately: a) treatment rooms; b) staff and c) diagnostic testing equipment;
3. **Processes**, the decision logic implemented in order to represent the patient’s logistic care pathways through the IEP Enschede.

The entities are moved around the simulation model's objects according to the processed defined, while the resources act on those entities. The processes prescribe which entities and resources are brought together into the treatment rooms implemented. These processes are implemented into the simulation model's methods, a programming environment in which the language "SimTalk" is used. The simulation's progress depends on the events simulated by the event controller. For example, the system's state is recalculated for includes the patient arrivals, the activation of processes, task completions, staff schedules and patient departures. Each event initiates one or multiple methods to execute their decision logic implemented.

A main frame is used as main menu within the simulation's graphical user interface. Once the user opens the simulation software, the "MainModel" frame is displayed first. The main frame include some controls that allow the user to activate, pause or exit the simulation experiments. The main frame also includes all other frames used for the simulation, which can be opened by clicking on the buttons located at the "MainModel" frame. Each frame included has its own unique purpose like visualizations, input settings, experiment results or information about the simulation's progress. The "Map" frame also includes a KPI dashboard and configuration panel. The simulation model's graphical user interface is (GUI) visualized in Figure 39. A full technical description of all the simulation model components and the main decision flow chart are given in Appendix P.

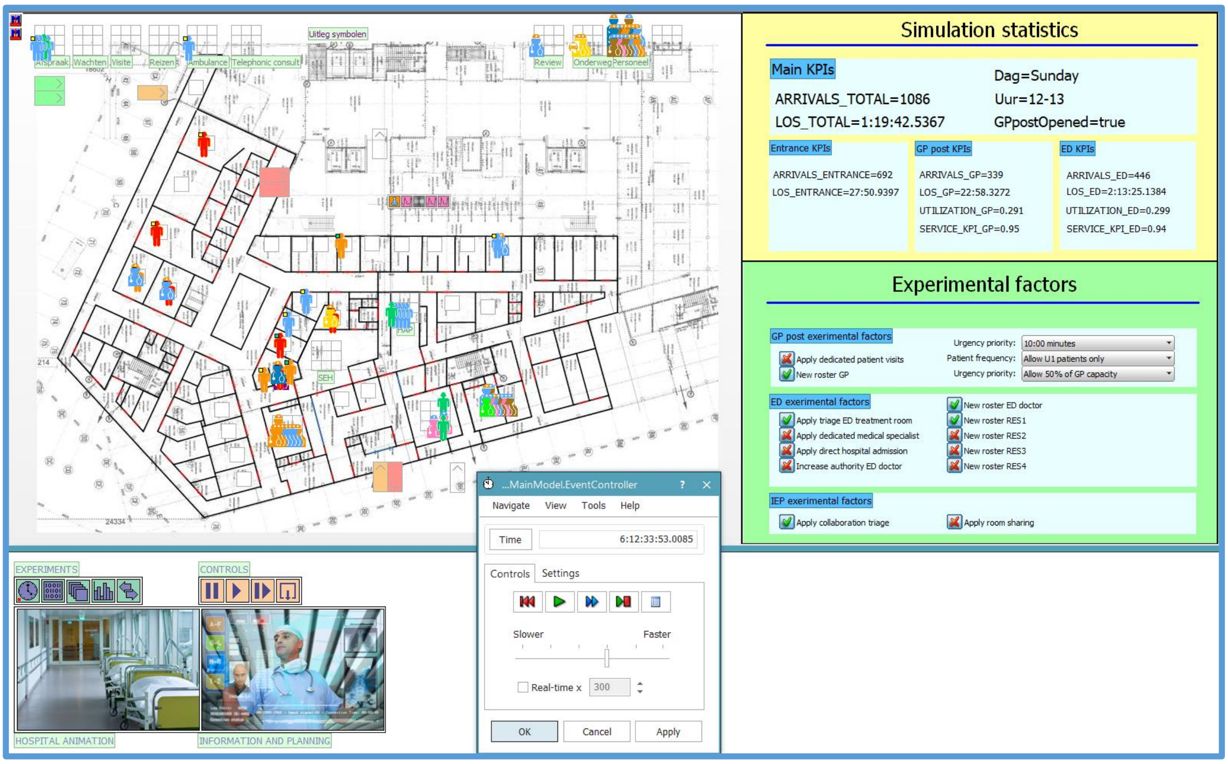


Figure 39: Visualization of the simulation model's graphical user interface, including the main frame, the event controller, the KPI dashboard, the configuration panel and the hospital visualization.

6.2. Model improvements

The conceptual model changed over the years due to changing patient arrivals, resource allocations and decision flows. The most important changes made in Koster's simulation model are discussed in Section 4.7. In order to make the simulation model up to date, all the modifications made into the conceptual model should be implemented into the model made by Koster (2014). Some of the modifications require the adaption of input variables only, these input modifications were already discussed in chapter 5. Other modifications require some new coding of decision logic.

Appendix Q provides an overview of all modifications made into the simulation model's decision logic. The main decision logic concerning the creation, prioritization and execution of tasks is not altered (for more details see Appendix P). However, new table files, variables and methods were required to make the simulation model up-to-date, as described in the following sub-sections.

6.2.1. New input variables

The conceptual model in Chapter 4 includes some new input variables in comparison with the simulation study performed by Koster (2014). For example, the GP post includes new physical and telephonic consult types, while the ED treatment group allocations are modified. The ED can also call external staff members from the hospital to the ED if required, this was not taken into account before. New table files are implemented in the "Settings" frame to insert the new variables' values. Table files are used on purpose, because this will improve the simulation model's reusability. If the model is used to simulate other IEPs, the investigator should only fill other data values into the "Settings" table files.

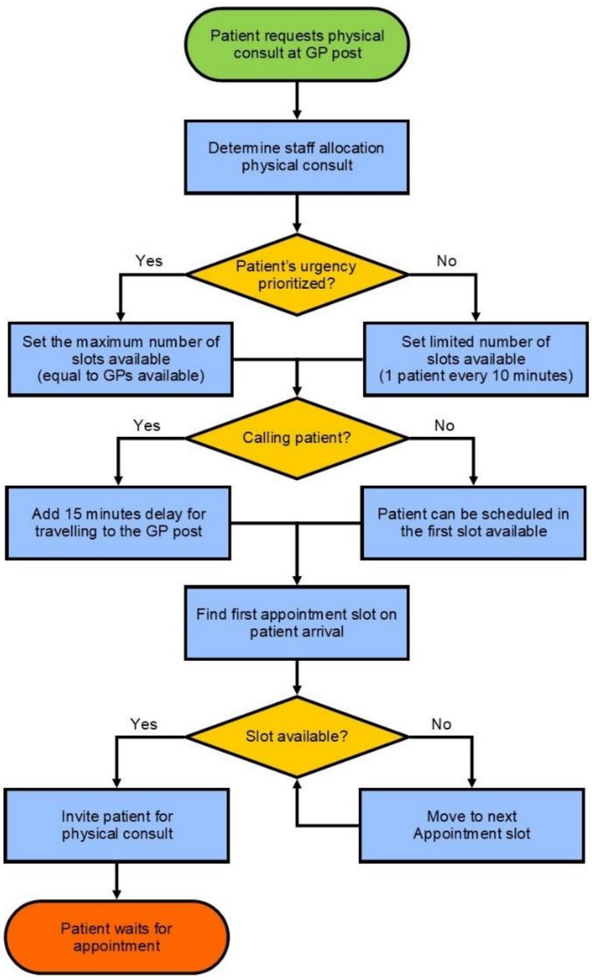


Figure 40: Decision logic flow chart corresponding to the GP post's appointment strategy.

6.2.2. New decision logic

All the original decision logic implemented by Koster (2014) has been evaluated again to understand how the simulation works exactly, as described in Appendix P. The hard-coded implementation of variable values is resolved by creating new table files, which improves the reusability of the simulation model. However new methods were still required to implement the GP post's altered appointment strategy, patient visits at home and staff allocations. The ED processes also require new decision logic for the patient's label classification, the transfer of treatment responsibility and the staff allocations from external departments. Ed nurses can also take over the physical triage of self-referrals during the night. The most complex and redesigned decision logic is required for the alternative appointment strategy implemented by the GP post. The corresponding decision logic is therefore visualized in Figure 40.

6.2.3. New GUI

The simulation model's GUI is also extended with a KPI dashboard and a configuration panel. The improved GUI allows the end user to perform single experiments and evaluate the KPI performances immediately. New variables, methods and table files were implemented in the "Performance" frame to make the new GUI work properly. Unfortunately, the GUI modifications are not reusable for other hospitals however, because the KPI definitions and experimental factors are only useful within the context of the IEP Enschede.

6.3. Model verification & white-box validation

It should be verified if the conceptual model's components are adequately implemented into the simulation model in order to assure a proper simulation of the real-world problem context. Both Law (2015) and Robinson (2004) states that is verification is concerned with determining whether the conceptual model is correctly translated into the simulation software. In order to verify the decision logic implemented, several techniques proposed by both Law and Robinson are applied:

1. All decision logic implemented in the simulation model of Koster (2014) are checked and commented in order to gain understanding of the processes implemented. The results of verification activity is included in Appendix P;
2. Newly created decision logic is moderately designed, tested and evaluated. The decision logic is implemented into a separate method in order to gradually debug the new lines of code. The modular design also enables the quick reuse of the same decision logic by multiple events or other methods;
3. Visual checks are made for all the simulation model's events. All type of patient arrivals and staff member allocations are tracked in order to gain insight into the item's progress;
4. Extreme conditions are simulated in order to obtain bugs into the decision logic. For example, by increasing the number of patient arrivals or decreasing the number of staff hired, critical errors can be identified earlier because the system operates almost at full capacity;
5. A comparison is made between the input variables inserted into the simulation model and the actual inputs gained once the simulation model completed a full replication consisting of two operational years.

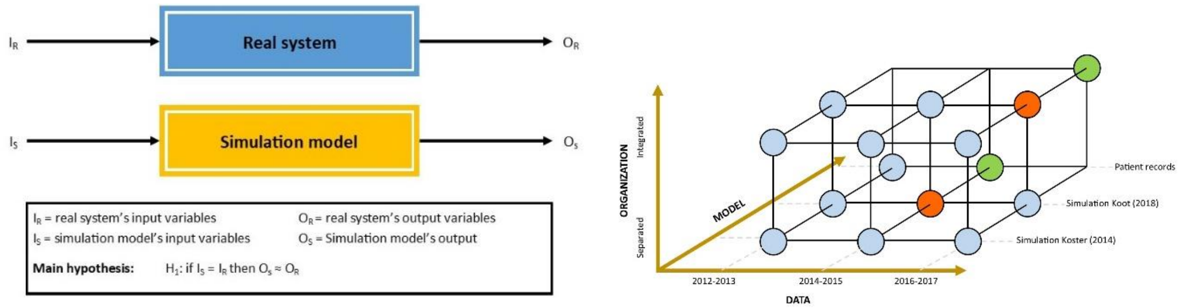
It can be concluded that the simulation model works properly without any bugs. Events are correctly created and allocated to one of the care pathways defined within the conceptual model. The comparison between the actual and simulated input variables are given within Appendix R, no significant differences can be observed for both the separated (2014-2015) and integrated (2016-2017) emergency care organization in Enschede. The number and type of patient arrivals are modelled correctly, the frequencies corresponding to the patients' care pathways and urgency classifications are allocated properly and the processing times are generated according to the probability function hypothesized.

6.4. Black-box validation

6.4.1. Customizing the validation framework

The literature study in Chapter 2 revealed that the simulation model should represent the real world with sufficient accuracy in order to meet the simulation study's objectives (Robinson, 2004). Therefore, the simulation model's results should be compared to the information stored within the patient records' from both the GP post and ED. If both the real system and the simulation model have the same type of input variables originating from the patient records, the overall results of both systems should be the same hypothetically (Figure 41a).

The data sets of both the separated (2014-2015) and the integrated (2016-2017) emergency care organizations can be used to create two sets of input variables. The two data sets make it possible to validate the new simulation model twice and increase the simulation model's reliability. The two data sets originating from the patient records are compared to the simulation models' output, including two types of configurations (separated versus integrated emergency care). The validation comparisons discussed can be visualized in the solution validation framework discussed in Chapter 2. The customization of the solution validation framework is visualized in Figure 41b and will be discussed in more detail in Chapter 7.



a) Black-box validation model (Robinson, 2004) *b) Relevant research model components*

Figure 41: The concept of solution validation (left) and the link to the research model's components (right).

6.4.2. Validation KPIs

The patient's length of stay (LOS) is one of the KPIs used to determine the configurations' performance (see Section 4.3). Both the GP post and the ED include proper registrations of the patient's arrival and departure times. Therefore, analyzing the patient's LOS makes it possible to validate the simulation model's performances against the real-world's results. The patient's LOS is separated into two components:

1. **The GP post LOS:** time between the patient's arrival and departure at the GP post physically.
2. **The ED LOS:** the time in between the patient's arrival and departure at the ED.

The first KPIs is determined from the GP post patient records, while the second KPI is based on the data gathered by the ED. The GP post's entrance LOS is are excluded due to the large complexity included by determining the appointment's time in real-life. The LOS for the GP post and the ED are also separated for each urgency classification. Only patient records are taken into consideration with a LOS value less than 10 hours for both the GP post and the ED separately.

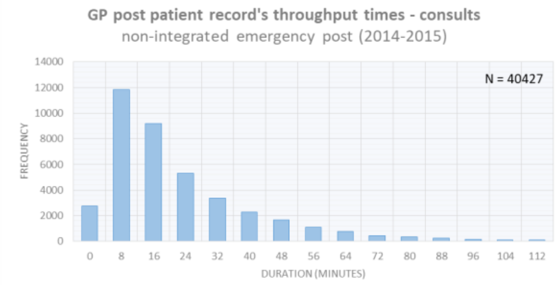
6.4.3. Validation of the separated organization (2014-2015)

The patient records representing the separated emergency organization (2014-2015) are inserted as input variables into the simulation model first. The patient records' LOS values are compared to the simulation results, visualized by the green and orange respectively in Figure 41b. The patients' LOS distributions are given in Table 27, the same colour labels are used as given earlier in Figure 41b. The differences between the actual and simulated average LOS are too small to conclude any significant difference for both the GP post and the ED. The LOS variances simulated also look similar to the values obtained from the patient records.

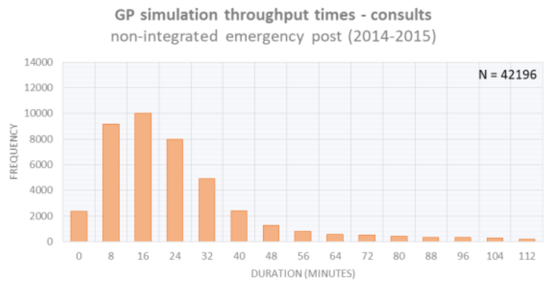
Statistics	LOS GP post		LOS ED	
Simulation model Koot 2018	Patient records 2014-2015	Simulation model 2014-2015	Patient records 2014-2015	Simulation model 2014-2015
Population size	42014	42288	53535	54611
Mean	28,68	30,34	138,15	140,07
Median	20,33	23,58	131,00	136,00
Mode	16,85	35,00	129,00	161,57
Standard deviation	28,12	25,82	71,54	71,52
Variance	790,56	666,86	5117,85	5114,95
Skewness	4,60	2,80	0,76	1,05
Kurtosis	39,87	10,27	0,98	3,30
Range	584,82	251,72	598,00	736,97
Minimum	0,87	3,00	0,00	10,17
Maximum	585,68	254,72	598,00	747,13

Table 27: Descriptive statistics of the actual and simulated LOS distributions for both the GP post and the ED during the separated emergency care organization(2014-2015).

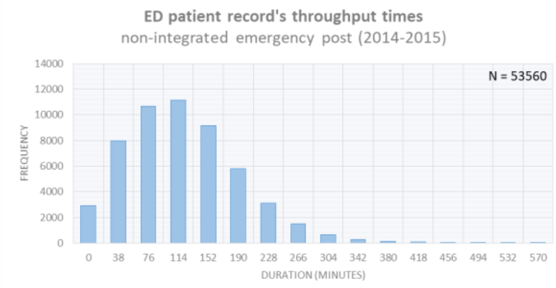
The LOS distributions corresponding to the results in *Table 27* are visualized in Figure 42. The distributions resulting from the simulation model and the patient records look relatively the same, especially the shapes of the entrance LOS and the ED LOS look very similar to each other. The actual GP post's LOS is more tailed around 10 minutes approximately, which also explains why the GP post LOS distribution is more skewed to the left in real-life. The ED LOS distribution look very similar to each other, most of the statistics' values are very close for both the actual and simulated LOS values.



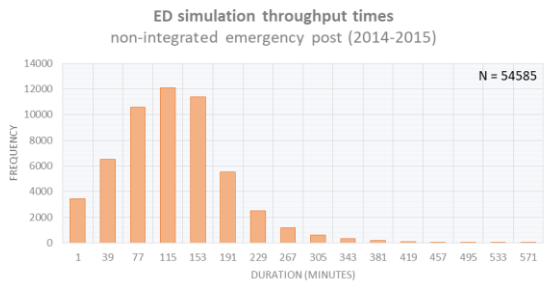
a) Patient record's LOS GP post physical consults.



b) Simulated LOS GP post physical consults.



c) Patient record's LOS ED.



d) Simulated LOS ED.

Figure 42: The actual and simulated patient's LOS distributions of the separated GP post and ED in between 2014-2015.

The patient's LOS mainly depends on the care pathway allocated, as described in Chapter 4 and Chapter 5. However, stakeholders from the GP post and the ED indicate that the LOS also differ for each urgency classification. Therefore, it should be evaluated if the pathway allocations result into the correct durations for all urgency levels (Table 28). The average GP post's LOS simulated seems to be a little bit higher than expected (+4%), while the ED LOS is simulated quite accurately (+1%).

Urgency classification (2014-2015)		Patient records		Simulation model		Difference	
		Record count	Length of stay	Record count	Length of stay	Record count	Length of stay
GP post	U0	-	-	-	-	-	-
	U1	106	23.80	120	14,98	13%	-37%
	U2	7031	26.64	7199	23,35	2%	-12%
	U3	24851	29.65	24812	28,66	0%	-3%
	U4	8259	29.31	8284	37,68	0%	29%
	U5	1767	31.18	1865	38,42	6%	23%
	TOTAL	**42014**	**28.68**	**42280**	**30.34**	**1%**	**6%**
ED	U0	880	115.54	892	122.66	1%	6%
	U1	7975	141.38	8254	141.29	3%	0%
	U2	27030	156.80	27531	158.39	2%	1%
	U3	17451	119.29	17782	112.42	2%	-6%
	U4	160	94.98	155	93.44	-3%	-2%
	U5	-	-	-	-	-	-
	TOTAL	**53496**	**138.14**	**54613**	**140.07**	2%	1%

Table 28: Verification of the urgency classifications assigned within the IEP Enschede (2014-2015).

The ED's LOS simulated matches the actual LOS quite well, only small differences are observed for the U0 and U3 patients. The GP post's results are not that perfectly aligned however. The simulation model treats high urgent patients (U1 and U2) too fast, while low urgent patients (U4 and U5) are consulted too slowly. The differences can be explained by the appointment strategy implemented. Patients are prioritized for a GP post consult by looking at their arrival/appointment time and the maximum waiting time allowed for the corresponding urgency classification. The patient with the lowest fictive waiting time is simply selected for a new consult, without taking any other attributes into account. This strategy explains the GP post's increasing LOS values per urgency class, low urgent patients simply have to wait longer. In real-life, the GPs also takes other attributes into account like the patient's condition, relevant entrance complaints, the patients' arrival sequence and expected durations. A combination of all these attributes explains why staff members invite lower urgent patient earlier in comparison with the simulation model's simplified appointment strategy.

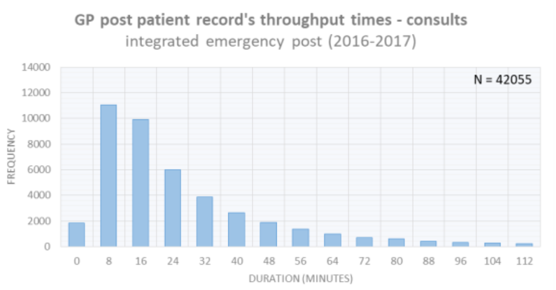
6.4.4. Validation of the integrated organization (2016-2017)

The patient records representing the integrated emergency organization (2016-2017) are inserted as input variables into the simulation model secondly. Once again, the patient records' LOS values are compared to the simulation results, visualized by the green and orange respectively in Figure 41b. The patients' LOS distributions are given in Table 29, the same colour labels are used as given earlier in Figure 41b. The differences between the actual and simulated average LOS is too small to conclude any significant difference for both the GP post and the ED, just like the results of the separated organization discussed in Section 6.4.3.The corresponding distributions are visualized in Figure 43.

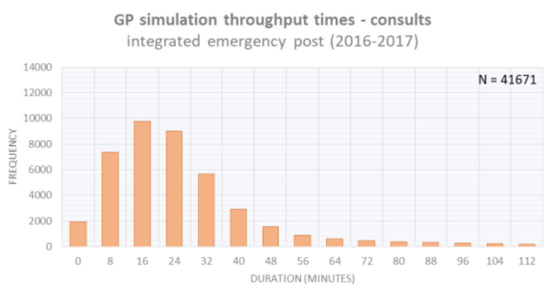
Statistics	LOS GP post		LOS ED	
Simulation model Koot 2018	Patient records 2016-2017	Simulation model 2016-2017	Patient records 2016-2017	Simulation model 2016-2017
Population size	42321	42386	46774	47301
Mean	33,77	31,44	159,05	160,90
Median	22,75	25,68	151,00	156,75
Mode	13,48	3,00	148,00	186,83
Standard deviation	35,62	24,68	77,07	69,07
Variance	1268,59	609,11	5939,74	4771,00
Skewness	4,51	2,86	0,74	1,08
Kurtosis	35,95	11,64	0,96	3,77
Range	598,77	260,80	598,00	868,92
Minimum	0,45	3,00	0,00	3,35
Maximum	599,22	263,80	598,00	872,27

Table 29: Descriptive statistics of the actual and simulated patient's LOS distributions for both the GP post and the ED during the integrated emergency care organization (2016-2017).

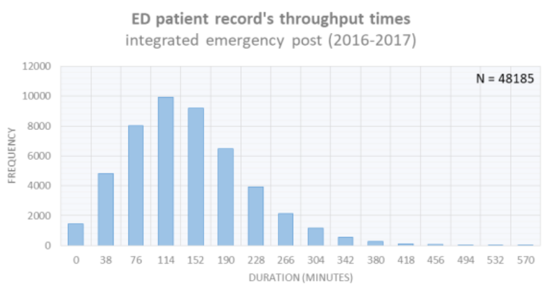
The actual and simulated distributions in Figure 43 look relatively the same, especially the shapes of the ED LOS look very similar to each other, which was expected, by the statistics given earlier. However, some differences can still be identified. The simulated patients leave the system too early with less variability in comparison with the patient records' LOS values. The actual GP post's LOS is more tailed around 10 minutes approximately, which also explains why the GP post LOS distribution is more skewed to the left in real-life.



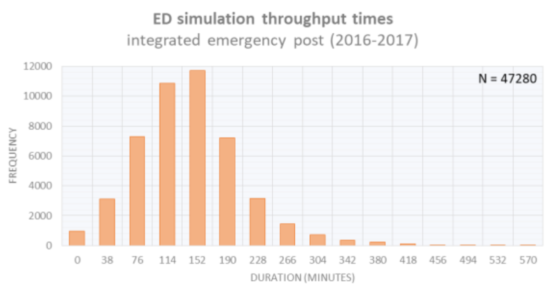
a) Patient record's length of stay GP post physical consults.



b) Simulated length of stay GP post physical consults.



c) Patient record's length of stay ED.



d) Simulated length of stay ED.

Figure 43: The actual and simulated patient's LOS distributions obtained from the IEP Enschede in between 2016-2017.

The durations also differ for each urgency classification (see Section 6.4.3). Therefore, it should be evaluated if the pathway allocations result into the correct durations for all urgency levels (Table 30).

Urgency classification (2016-2017)		Patient records		Simulation model		Difference	
		Record count	Length of stay	Record count	Length of stay	Record count	Length of stay
GP post	U0	-	-	-	-	-	-
	U1	79	22.58	79	19.33	0%	-14%
	U2	8184	29.55	8208	25.61	0%	-13%
	U3	25990	34.63	25967	30.79	0%	-11%
	U4	6104	34.70	6080	38.68	0%	11%
	U5	1964	40.40	2052	41.89	4%	4%
	TOTAL	**42321**	**33.77**	**42353**	**31.44**	**0%**	**-7%**
ED	U0	576	113.26	566	112.91	-2%	0%
	U1	6450	155.67	6687	156.86	4%	1%
	U2	20510	177.40	20934	178.47	2%	1%
	U3	17131	143.54	17693	146.31	3%	2%
	U4	1359	120.44	1421	121.96	5%	1%
	U5	-	-	-	-	-	-
	TOTAL	**46026**	**159.26**	**47301**	**160.90**	**3%**	**1%**

Table 30: Verification of the urgency classifications assigned within the IEP Enschede (2016-2017).

The simulation model treats the GP post patients too quickly on average in comparison with the actual LOS observed (-7%). The GP post's results are also not perfectly aligned across the five different urgency classifications. The simulation model treats high urgent patients (U1 and U2) too fast, while low urgent patients (U4 and U5) are consulted too slowly. The differences can be explained by the appointment strategy implemented, as discussed in the previous section. The GP post LOS increases in ascending order of the five available urgency classifications, the same pattern is observed for the separated organization. The GP post LOS differences are significant, but acceptable for the purpose at hand if the conceptual model's restrictions are taken into account. For example, higher simulation LOS values would be expected if the staff members are not immediately available once requested. On the other hand, the ED's LOS simulated matches the actual LOS almost perfectly, the results only differ +/- 2% for all urgency classifications.

6.5. Verification & validation conclusions

This chapter revealed how the conceptual model is translated into a new simulation model, based on the original model of Koster (2014). The simulation model's reusability is improved by inserting as many input variables into table files. New decision logic was required to simulate the GP visits and physical consults within the GP post itself properly. The GP post's appointment strategy, the staff allocations for physical GP consults and the availability of the GP post car are updated. New decision logic was also required for the simulation of ED processes, including the physical triage of self-referrals arriving at night, changing the ED rooms' availability, allowing the ED's emergency physicians to transfer responsibility of a patient's treatment and the possibility to invite residents to the ED from an external hospital department if required. ED treatment group allocations are also modified.

It can be concluded that the simulation model works properly without any bugs. Events are correctly created and allocated to one of the care pathways defined within the conceptual model. No significant differences of the simulation model's input variables can be observed for both the separated (2014-2015) and integrated (2016-2017) emergency care organization in Enschede. The number and type of patient arrivals are modelled correctly, the frequencies corresponding to the patients' care pathways and urgency classifications are allocated properly and the processing times are generated according to the probability function hypothesized.

It can be concluded that the new simulation model is valid for the solution validation purposes at hand. The model works properly for both the separated (2014-2015) and integrated (2016-2017) emergency care organization in Enschede. The GP post LOS is accurately defined on average, but the simplified appointment strategy results into improper distributions for each urgency classification. The GP post LOS differences are significant for the integrated simulation model (-7% on average), but acceptable for the purpose at hand if the conceptual model's restrictions are taken into account. The simulation model's input variables were changed only for both the separated and integrated organization, while the same simulation model is applied for both data sets. Therefore, the results are validated twice, which will support the simulation model's reliability.

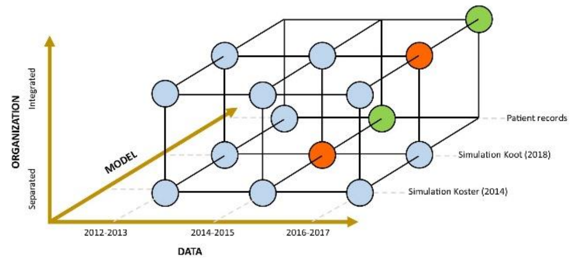
Chapter 7 – Solution validation

The main purpose of this research is to improve the understanding of the stakeholders within the out-of-hours emergency care in Enschede by validating the solutions obtained from a general discrete-event simulation framework developed by Koster (2014). The solution validation will try to assure the validity of the solution implemented: integrating the GP post and the ED into one organizational unit for the 24/7 emergency care in Enschede. The solution validation will provide an answer to research question 6.

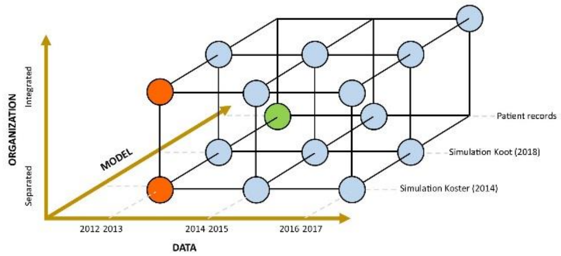
Research question 6: How do the performances differ for both the separated and integrated emergency care organization in Enschede from 2012 up to 2017?

7.1. Solution validation comparisons

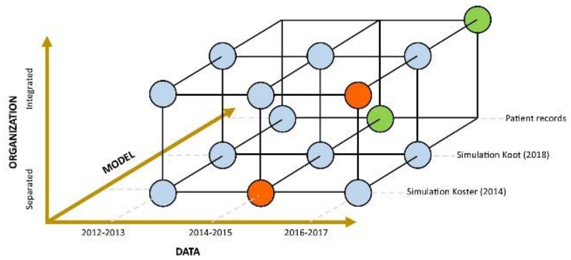
The main purpose of this research is to gain understanding of the logistic performances of the IEP Enschede by comparing the results obtained from the patient records and simulation models used. The literature study in Chapter 2 resulted into a generic framework which could be used for the solution validation, including three different dimensions: 1) data modifications; 2) model modifications and 3) alternative configurations. In order to validate the solutions recommended by Koster's simulation model, the generic research model should be customized, as visualized in Figure 44.



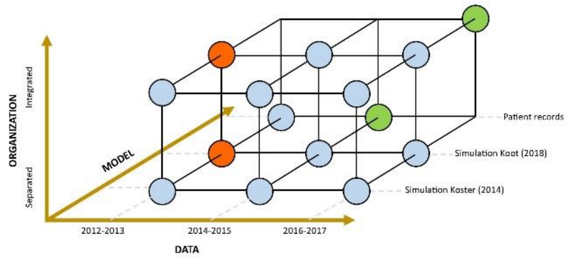
a) Section 7.2: Simulation validation of the simulation model discussed in this research (2014-2017)



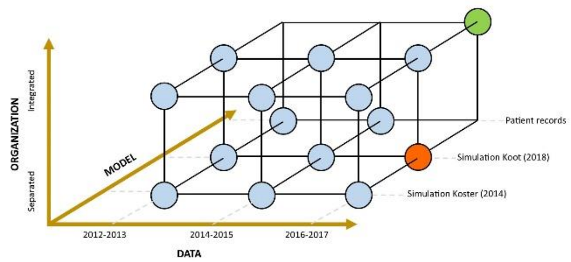
b) Section 7.3: Simulation validation of Koster'(2012-2013)



c) Section 7.4: Solution validation Koster's model versus new data developments (2014-2017)



d) Section 7.5: Solution validation current research's model versus old data developments (2012-2013)



e) Section 7.6: Separated versus integrated organization, based on today's data (2016-2017)

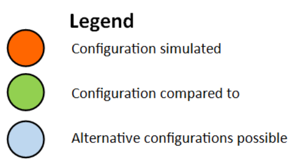


Figure 44: A visualization of the research model's components discussed in this chapter.

The customized research model consists of the following components:

1. **data modifications**: three alternative data sets, each with two years of patient arrivals:
    a. Separated organization investigated by Koster (2012-2013);
    b. Separated organization investigated in this research (2014-2015);
    c. Integrated organization investigated in this research (2016-2017).
2. **model modifications**: three alternative models are compared to each other:
    a. the simulation model developed by Koster (2014);
    b. the updated model used in this research and;
    c. the patient records representing the real world's performances;
3. **Configurations**: separated or integrated emergency organization in Enschede;

Figure 44 visualizes which research model components will be compared during the solution validation in this chapter. All the simulation models' results (orange nodes) will be compared with the actual results (green nodes) for either the separated organization or the integrated organization, based on the patient records from 2014-2015 or 2016-2017 respectively. Note that all input variables are changed only for the three research components taken into consideration. Alternative experiment configurations are not taken into account, these will be discussed in chapter 8. Also note that some nodes in Figure 44 are missing, simply because the patient records are also missing.

First, the results of each simulation model will be discussed shortly, in which Koster's model uses the input variables found in between 2012 and 2013, while the new simulation model will make use of more recent data from 2014 up to 2017. Second, the output variables of Koster's simulation model will be compared with the actual output variables for both the separated and integrated organization. This comparison will provide insights into the validity of the model developed by Koster (2014). Thirdly, the new simulation model developed in this research will be used in order to simulate the separated and integrated organization based on the data characteristics from 2012 and 2013, which makes it possible to identify the impact of changing input variables. Finally, the effects of integrating the GP post and the ED is investigated in more detail, because the separated emergency care organization will be simulated based on today's data (2016-2017).

7.2. New simulation model vs. new data

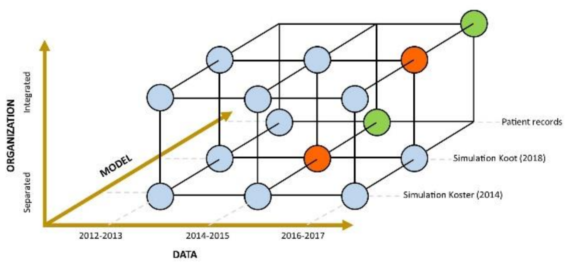


Figure 45: Research model component visualization.

7.2.1. Solution validation components

The output variables resulting from the new model developments were already discussed in Chapter 6. The reader is referred to chapter six for the table files and visualizations including all LOS results. In this section, the conclusions are discussed only.

The new simulation model developed will be runned for both the separated (2014-2015) and integrated (2016-2017) emergency care organization in Enschede. The simulation results are compared with the patient records from the corresponding years. Only the simulation model's input variables were changed for both the separated and integrated organization, the underlying decision logic remained exactly the two data sets simulated. Therefore, the results are validated twice, which will support the simulation model's reliability. It can be concluded that the new simulation model developed in this research works properly without any bugs. The solution validation results are presented in Section 6.4, the results of the model comparisons represented in Figure 45 will be discussed only.

7.2.2. *Separated emergency organization (2014-2015)*

The actual GP post LOS resulted to be equal to 28.68 minutes for the separated organization in 2014 and 2015, while the actual ED LOS was equal to 138.14 minutes during the same period (Table 27). The simulation model's results for the GP post LOS differ 6%, while the ED LOS matches approximately. The GP post LOS values increase in descending order of the patient's urgency classification due to the simplified appointment strategy (low urgent patients have to wait longer for their treatment).

7.2.3. *Integrated emergency organization (2016-2017)*

Over the years, the actual GP post LOS increased up to 33.77 minutes for the IEP Enschede (2016-2017), an increase of 17.7% in comparison with 2014 and 2015 (Table 29). The actual ED LOS also increased by 15.3% from 138.14 minutes for 2014 and 2015 up to 159.26 minutes for 2016 and 2017. Over the years, the LOS differences between urgency classifications increased, low urgent patients have to wait longer for their treatment The actual ED LOS increase is mainly observed for lower urgent patients (U2, U3 and U4 patients). The simulation model observed an increase of the ED LOS by 14.9%, which is relatively the same as observed in real-life. However, the simulated GP post LOS increased by 3.6% over the years, which is smaller than observed in real life. The differences can be explained by the implementation of the simplified appointment strategy. The simulation results of 2016 and 2017 are better aligned, because the simulation model also prioritizes high urgency patients more.

7.2.4. *Simulation output variables*

The waiting time and utilization rates simulated are examined more closely in order to gain more insight into the LOS increases (Table 31 and Appendix S). Only simulated values are included, because the patient records do not include all essential information in order to calculate these type of output variables. Most of the GP post activities' waiting times decreased over the years, which indicates that the GP post LOS should be increased due to longer activity durations. The ED LOS increase can be explained by the increasing residents' workloads due to changing distributions of patient arrival types. However, more validation techniques are required in order to proof these initial conclusions found.

Organization	Activities' waiting times	Separated (2014-2015)	Integrated (2016-2017)
GP post	Telephonic triage	00:00:07	00:00:11
	Physical triage	00:00:15	00:01:19
	GP visit home	00:45:05	00:39:43
	Wait for appointment	00:26:16	00:23:07
	GP physical consult	00:18:33	00:18:09
	GP telephonic consult	00:16:52	00:15:08
	NP physical consult	00:09:44	00:11:17
	GP assistant physical consult	00:06:16	00:07:10
ED	Physical triage	00:00:28	00:04:11
	Anamnesis 1 – nurse	00:01:17	00:00:34
	Anamnesis 2 – resident	00:19:32	00:19:20
	Ultrasound	00:04:43	00:04:23
	Lab	00:02:30	00:02:12
	X-ray	00:06:16	00:04:04
	ECG	00:01:48	00:01:37
	CT	00:04:09	00:02:50
	Treatment	00:43:46	00:48:47
	Plaster	00:23:30	00:34:38

a) Simulation model waiting times (Koot, 2018)

Organization	Staff member utilization rates	Separated (2014-2015)	Integrated (2016-2017)
GP post	Nurse practitioner	27,1%	32,7%
	Telephonic GP assistant	28,8%	31,7%
	Physical triage assistant	6,3%	20,0%
	Coordinating GP assistant	12,5%	15,8%
	General practitioner	52,5%	49,4%
	Circulating GP assistant	2,6%	8,0%
	Nurse	17,8%	19,2%
	Physical triage nurse	16,3%	33,6%
ED	Directing nurse	2,8%	11,3%
	Emergency physician	57,5%	49,0%
	Resident 1 – Surgery & Orthopedics	49,0%	53,8%
	Resident 2 – Internal medicine	20,9%	24,9%
	Resident 3 – Neurology	33,9%	37,7%
	Resident 4 – Pulmonary medicine	32,1%	38,8%

b) Simulation model utilization rates (Koot, 2018)

Table 31: Simulation output variables resulting from the new simulation model developed by Koot (2018). Green colored fields represent low waiting times or low utilization rates respectively, while red colored fields represent high valued ones. The colors are relatively determined by looking at the table file's minimum and maximum values. The color indications indicate which activities' waiting times or staff member's utilization rates changed significantly over the years.

7.3. Old simulation model vs. old data

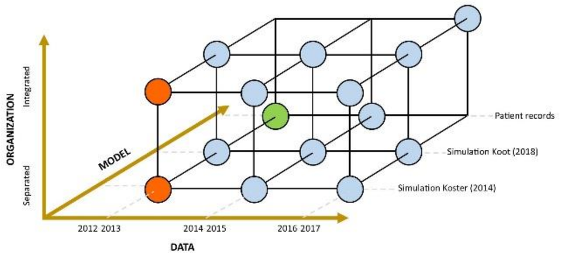


Figure 46: Research model component visualization.

7.3.1. Solution validation components

The simulation model developed by Koster (2014) is used to explain how the IEP can be organized in the most efficient way. Several interventions are simulated and evaluated by looking at the resulting LOS values (Table 32), all input variables are based on the patient records obtained in between 2012 and 2013 (Figure 46).

7.3.2. Separated emergency organization (2012-2013)

Koster (2014) observed that the actual GP post LOS was equal to 32.26 minutes for 2012 and 2013 while the ED LOS was equal to 120.35 minutes for the same period (Table 32). A difference of -15.7% is observed between the actual and simulated GP post LOS, which is explained by the simplified appointment strategy and insufficient data registrations. The ED LOS is accurately predicted by the simulation model.

Statistics	LOS GP post		LOS ED	
Simulation model Koster 2014	Patient records Separated 2012-2013	Simulation model Separated 2012-2013	Patient records Separated 2012-2013	Simulation model Separated 2012-2013
Patient arrivals	94864	91304	30622	30324
Mean	32,36	27,27	120,35	118,81

Table 32: Solution validation results corresponding to the simulation model developed by Koster (2014), based on data of the separated emergency care in Enschede (2012-2013). This run is used for validation only.

7.3.3. Integrated emergency organization (2012-2013)

Koster (2014) predicted that the GP post LOS would increase by 27.2% due to the integration (Table 33). The increased number of self-referral arrivals at the GP post should be treated with the same number of resources. The increasing number of GP post patients also results into more ED patients that are referred by the GP post, causing an increase of 19.7% in the ED LOS. The increase in GP post referrals increases the ratio of labeled patients at the ED, which utilizes the residents too much while the the emergency physicians' workload is reduced. Therefore, the implementation of the IEP would result into an increase of the LOS for both the GP post and the ED.

Statistics	LOS GP post		LOS ED	
Simulation model Koster 2014	Patient records Separated 2012-2013	Simulation model Integrated 2012-2013	Patient records Separated 2012-2013	Simulation model Integrated 2012-2013
Patient arrivals	94864	91304	30622	30324
Mean	32,36	41,64	120,35	154,46

Table 33: Solution validation results corresponding to the simulation model developed by Koster (2014), based on data of the separated emergency care in Enschede (2012-2013). This run is used to investigate the IEP performances.

However, Koster (2014) also conducted multiple experiments in order to reduce the LOS values for both the GP post and the ED. The best results were obtained by implementing three new configurations: 1) allowing the emergency physician to treat both unlabeled and labeled patients; 2) using an additional NP the GP post and 3) make use of the same triage system, which makes the ED triage activity unnecessarily.

7.4. Old simulation model vs. new data

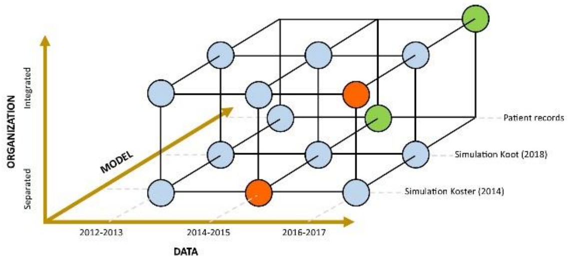


Figure 47: Research model component visualization.

7.4.1. Solution validation components

In order to validate the simulation model developed by Koster (2014), the model should be runned including today's input variables (Table 34). Koster's model will be valid once the simulation model's output variables are comparable for today's performances.

7.4.2. Data modifications

Most of the input variables discussed in chapter 5 can be used in order to simulate the separated GP post and ED (2014-2015) and the IEP Enschede (2016-2017). The patients' urgency classifications, care pathways allocations and diagnostic test requirements can be implemented into the table files of the simulation model's "Settings" frame. Also the staff allocations, room allocations and activity durations can be updated by simple replacements. However, the simulation model developed by Koster (2014) does not include all the components of today's conceptual model. Therefore, simply copying all today's input variables will not work completely, the variables are simply not defined in Koster's simulation model. Several modifications are required to make Koster's simulation model work properly. All data modifications are described in more detail in Appendix T. Note that not all today's input variables and decision logic can be used in Koster's simulation model (2014), assumptions were therefore required.

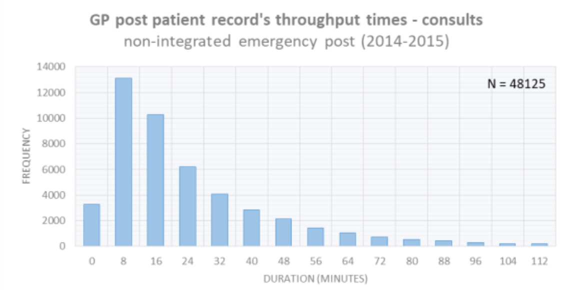
7.4.3. Separated emergency organization (2014-2015)

First the simulation model developed by Koster (2014) will be runned in order to simulate the separated emergency care organization. The input variables are based on the patient records from between 2014 and 2015. The distribution statistics of both the separated GP post LOS and ED LOS are given in Table 34, while the corresponding distributions are visualized in Figure 48. The simulation's waiting times and utilization rates are visualized in Appendix S.

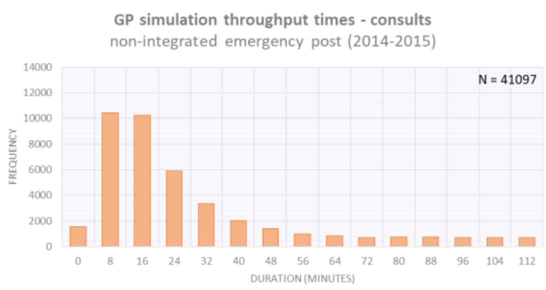
Statistics	LOS GP post		LOS ED	
Simulation model Koster 2014	Patient records 2014-2015	Simulation model 2014-2015	Patient records 2014-2015	Simulation model 2014-2015
Patient arrivals	48108	50151	53535	56684
Mean	32,19	60,66	138,15	86,29
Median	21,54	27,18	131,00	62,43
Mode	16,85	13,37	129,00	43,27
Standard deviation	35,65	70,41	71,54	69,43
Variance	1271,24	4957,18	5117,85	4820,48
Skewness	4,94	2,08	0,76	3,41
Kurtosis	41,23	5,91	0,98	21,77

Table 34: Descriptive statistics of the actual and simulated patients' LOS distributions for both the GP post and the ED during the separated emergency care organization. The simulation model developed by Koster (2014) is used, while the input variables are originating from in between 2014-2015. The GP post patient records include both physical and telephonic consults, which explains the increase in patient arrivals.

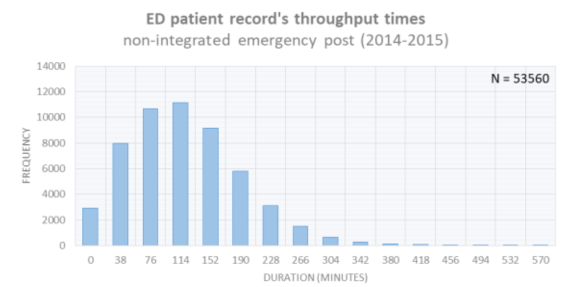
The actual GP post LOS should be equal to 28.68 minutes for the separated organization in 2014 and 2015. However, telephonic consults cannot be included in Koster's model properly and are therefore seen as patients that physically visit the GP post itself, increasing the GP post LOS to 32.19 minutes. The actual ED LOS remained unchanged and is equal to 138.14 minutes during the same period. Koster's simulation model reveals significant different results for both the GP post LOS and the ED LOS. The simulated GP post LOS is equal to 60.66 minutes, an 88% increase in comparison with the actual GP post LOS in 2014 and 2015. The durations simulated are also more skewed to the left and the number of extreme outliers have increased. The ED LOS simulated by Koster's model is equal to 86.29 minutes, a decrease of 38% in comparison with the actual ED LOS in 2014 and 2015.



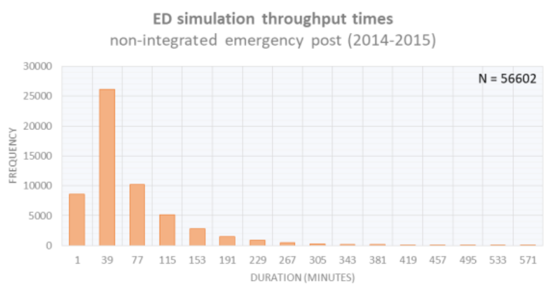
a) Patient record's length of stay GP post physical consults.



b) Simulated length of stay GP post physical consults.



c) Patient record's length of stay ED.



d) Simulated length of stay ED.

Figure 48: The actual and simulated patient's LOS distributions obtained from the separated emergency care organization in Enschede (2014-2015). The simulation model developed by Koster (2014) is used. The patients used for the GP post LOS calculations also include telephonic consults (care pathway A9), which explains the increase in GP post patients.

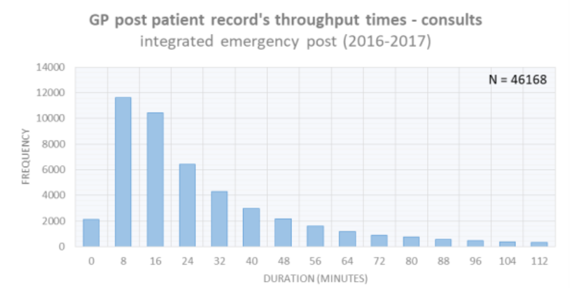
7.4.4. Integrated emergency organization (2016-2017)

The simulation model developed by Koster (2014) will be activated in order to simulate the integrated emergency care organization in Enschede. The input variables are based on the patient records from between 2016 and 2017. The distribution statistics of the integrated GP post LOS and ED LOS are given in Table 35, while the corresponding distributions are visualized in Figure 49. The differences between the simulation model's results and the actual results of the integrated emergency organization (2016-201) will provide insights into the validity of the model developed by Koster (2014). The model made by Koster relies on a more simplified conceptual model, the question arises if this model is able to represent actual integrated emergency organization adequately.

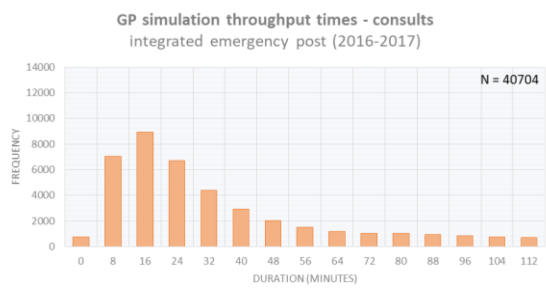
Statistics	LOS GP post		LOS ED	
Simulation model Koster 2014	Patient records 2016-2017	Simulation model 2016-2017	Patient records 2016-2017	Simulation model 2016-2017
Patient arrivals	48491	50122	48185	48630
Mean	38,69	66,23	158,77	101,21
Median	24,07	34,75	151,00	83,67
Mode	14,45	18,80	140,00	62,78
Standard deviation	46,48	70,85	77,01	63,06
Variance	2160,18	5020,17	5930,93	3977,02
Skewness	4,51	2,15	0,74	2,50
Kurtosis	30,77	6,73	0,95	11,93

Table 35: Descriptive statistics of the actual and simulated patients' LOS distributions for both the GP post and the ED during the integrated emergency care organization. The simulation model developed by Koster (2014) is used, while the input variables are originating from in between 2016-2017. The GP post patient records include both physical and telephonic consults, which explains the increase in patient arrivals.

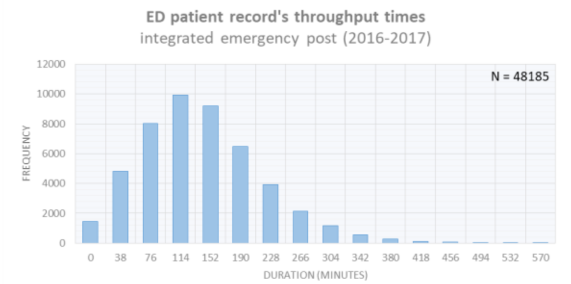
The actual GP post LOS is equal to 33.77 minutes for the IEP Enschede (2016-2017), which forms an increase of 17.7% in comparison with 2014 and 2015. The actual ED LOS also increased by 15.3% from 138.14 minutes for 2014 and 2015 up to 159.26 minutes for 2016 and 2017. These results are not comparable with the results from Koster's simulation model. The GP post LOS is simulated too high again, resulting into an average of 66.23 minutes. The ED patients still leave the simulation model too early, resulting into an ED LOS of 101.21 minutes.



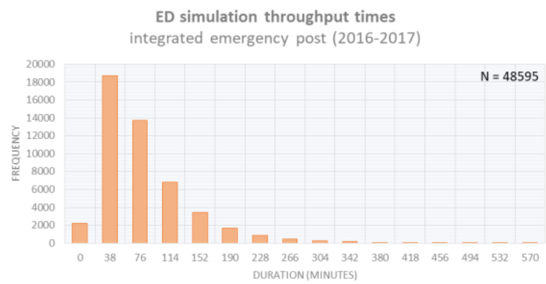
a) Patient record's length of stay GP post physical consults.



b) Simulated length of stay GP post physical consults.



c) Patient record's length of stay ED.



d) Simulated length of stay ED.

Figure 49: The actual and simulated patient's LOS distributions obtained from the IEP Enschede in between 2016-2017. The simulation model developed by Koster (2014) is used. The patients used for the GP post LOS calculations also include telephonic consults (care pathway A9), which explains the increase in GP post patients.

The GP post LOS is clearly overestimated by Koster's simulation model. The average duration simulated is too high, +71.2% in comparison with today's actual GP post LOS. This is less in comparison with the separated emergency care organization, but the differences are still far too large. The GP post's LOS values, waiting times and utilization rates are approximately the same as observed for the separated simulation discussed in the previous section. The ED LOS simulated is too low,-37.2% in comparison with today's actual ED LOS. The ED patients simulated leave the system too early, resulting in both low activity durations and low patient's waiting times. The ED's LOS values, waiting times and utilization rates are approximately the same as observed for the separated simulation discussed in the previous section.

7.5. New simulation model vs. old data

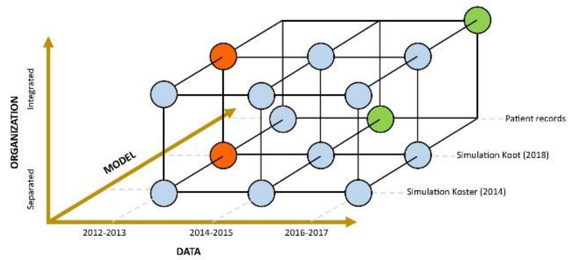


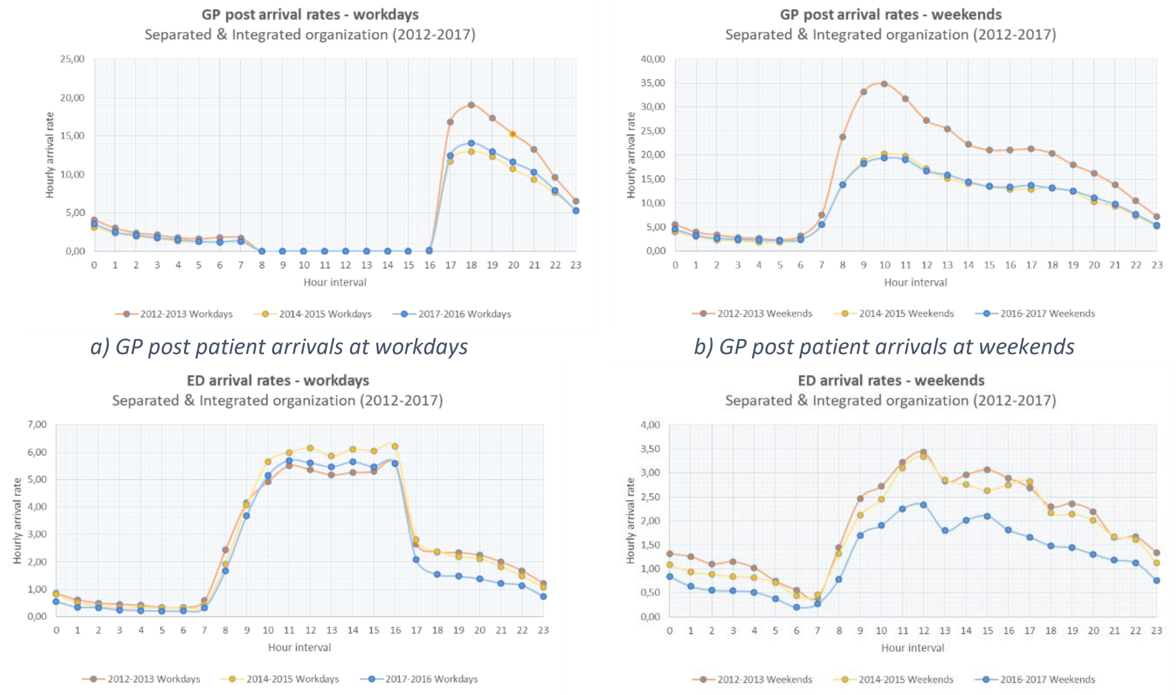
Figure 50: Research model component visualization.

7.5.1. Solution validation components

The previous section revealed that the simulation model developed by Koster (2014) is not adequate to simulate the GP post and ED activities reliable anymore. The underlying conceptual model changed too much in order to make useful recommendations based on the simulation results, which seems a valid reason in order to conclude that Koster's model is not valid anymore. However, this cannot be fully proven yet, because the differences in both the GP post and LOS values may also result from the changing input variables in 2012 and 2013. The results also do not prove which effects did result from the implementation of the IEP Enschede .Therefore, the new simulation model developed in this research will be used to simulate both the separated and the integrated emergency care in Enschede, based on the patient arrivals, processes and resource allocations for 2012 and 2013. The simulation model results are compared to the patient records of 2014-2015 and 2016-2017 (Figure 50).

7.5.2. Data modifications

Chapter 5 revealed already that the input variables changed in value over the years, which could partly explain why Koster's simulation results do not match with today's practices. However, some trends are originating from before the GP post and the ED integrated into one organization. Koster analyzed the same type of input variables discussed in chapter 5, but she used the patient records originating from for 2012 and 2013 in order to define the input variables' values. A full description of the data analytics for 2012 and 2013 is given in Appendix U. Only the changing patient arrival patterns are visualized in Figure 51, these are required to explain why the activity durations increased over the years.



a) GP post patient arrivals at workdays

b) GP post patient arrivals at weekends

c) GP post patient arrivals at workdays

d) GP post patient arrivals at weekends

Figure 51: The patient arrival patterns and arrival rates for each data set simulated.

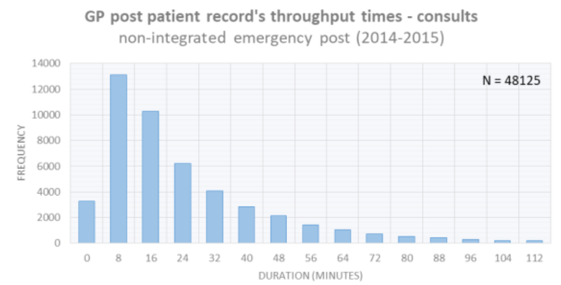
Note that today's simulation model includes more input variables in comparison with the model developed by Koster (2014). Therefore, most input variables are updated by the values found in the patient records originating from 2012 and 2013. However, today's input variables are used if the variables cannot be obtained from the patient record and simulation model used by Koster. Examples are summarized in Appendix U.

7.5.3. Separated emergency organization (2012-2013)

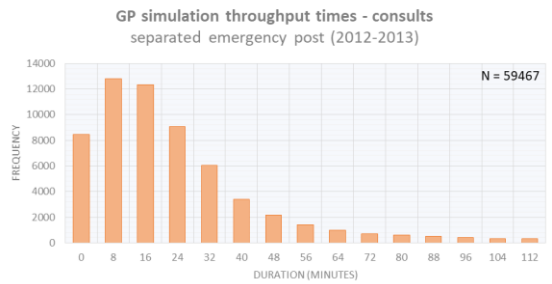
First the new simulation model developed by Koot (2018) will be runned in order to simulate the integrated emergency care organization in Enschede. The input variables are based on the patient records from between 2012 and 2013. The distribution statistics of both the separated GP post LOS and ED LOS are given in Table 36, while the corresponding distributions are visualized in Figure 52. The simulation's waiting times and utilization rates are visualized in Appendix S. The simulated LOS values are compared to the patient records' LOS values gathered during the separated emergency care organization in between 2014 and 2015. The differences between the simulation model's results (2012-2013) and the actual results of the separated emergency organization (2014-2015) will provide insights into the input variables and the corresponding changes that have taken place before the actual integration of the GP post and the ED.

Statistics	LOS GP post		LOS ED	
Simulation model Koot 2018	Patient records Separated 2014-2015	Simulation model Separated 2012-2013	Patient records Separated 2014-2015	Simulation model Separated 2012-2013
Patient arrivals	42014	60663	53535	55318
Mean	28,68	29,68	138,15	162,77
Median	20,33	21,80	131,00	133,48
Mode	16,85	3,00	129,00	126,02
Standard deviation	28,12	29,67	71,54	126,03
Variance	790,56	880,29	5117,85	15882,74
Skewness	4,60	3,14	0,76	2,54
Kurtosis	39,87	14,30	0,98	9,22

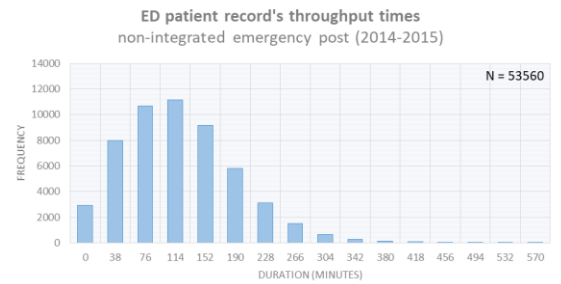
Table 36: Descriptive statistics of the actual and simulated patients' LOS distributions for both the GP post and the ED during the separated emergency care organization. The simulation model developed by Koster (2014) is used, while the input variables are originating from in between 2014-2015.



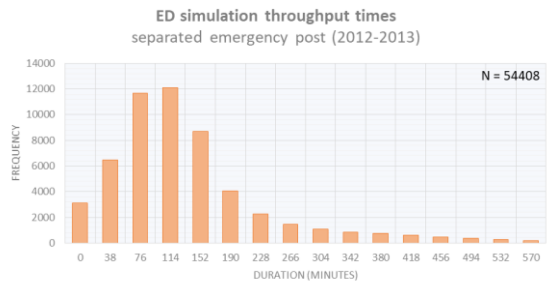
a) Patient record's length of stay GP post physical consults.



b) Simulated length of stay GP post physical consults.



c) Patient record's length of stay ED.



d) Simulated length of stay ED.

Figure 52: The actual and simulated patient's LOS distributions obtained from the separated emergency care organization in Enschede (2014-2015). The simulation model developed by Koster (2014) is used. The patients used for the GP post LOS calculations also include telephonic consults (care pathway A9).

The number of GP post patient arrivals simulated is higher for the actual patient arrivals in 2012 and 2013, as expected by Figure 51. The actual GP post LOS in 2014 and 2015 is equal to 28.68 minutes, while the simulation results based on the input variables of 2012 and 2013 result into a simulated GP post LOS of 29.68 minutes. The simulation model predicts a GP utilization of 69.7%, while the actual GP utilization is equal to 52.5% for 2014 and 2015. The patient's waiting time at home is larger for the simulation model than observed in real-life (26 minutes and 1 hour and 27 minutes respectively). Patients also have to wait longer at home if the patient is visited at home by a GP. Koster also observed that more non-urgent patients were treated by the GP post during 2012 and 2013, these patients include a lower activity duration on average (Section 6.4.3.).

The number of ED patient arrivals did not changed significantly in between 2012 and 2013. However, the actual and simulated ED LOS values of 138.17 and 162.77 minutes respectively differ significantly. This is mainly due to improper staff allocations. The simulation model predicts a higher workload for the surgery/orthopedic residents, the utilization rate simulated equals 66.6%, which is larger than the rate of 49.0% observed for 2014 and 2015. The emergency physicians' utilization rate simulated equals 21.0%, while its utilization would be higher in real-life (57.5%). Therefore, the type of patient arrivals for 2012 and 2013 differ significantly, especially the patient's arrival types and label classifications.

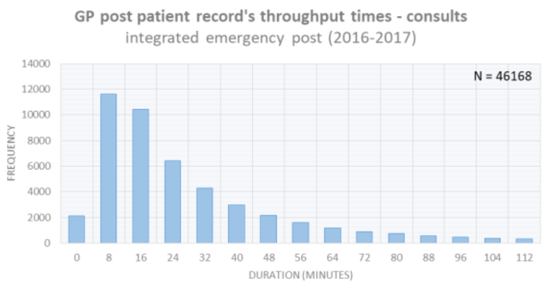
Note that the waiting time simulated for the first anamnesis step performed by the ED nurse also increases, because most GP post patients have to wait in the ED's waiting room before a room allocation becomes available. More urgent patients arrived in between 2012 and 2013, which negatively influence the waiting time for low urgent patients.

7.5.3. New simulation results – integrated organization (2012-2013)

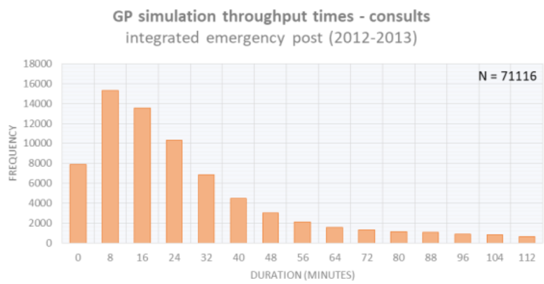
The new simulation model developed in this research will be activated in order to simulate the integrated emergency care organization in Enschede. The input variables are based on the patient records from between 2012 and 2013. The distribution statistics of both the separated GP post LOS and ED LOS are given in Table 37, while the corresponding distributions are visualized in Figure 53. The simulated LOS values are compared to the patient records' LOS values gathered during the integrated emergency care organization in between 2016 and 2017. The differences between the simulation model's results (2012-2013) and the actual results of the integrated emergency organization (2016-2017) will provide insights into the input variables and the corresponding changes that have taken place before the actual integration of the GP post and the ED at the 11th of January 2016.

Statistics	LOS GP post		LOS ED	
Simulation model Koot 2018	Patient records Integrated 2016-2017	Simulation model Integrated 2012-2013	Patient records Integrated 2016-2017	Simulation model Integrated 2012-2013
Patient arrivals	42321	74698	46774	48050
Mean	33,77	37,26	159,05	251,34
Median	22,75	24,38	151,00	158,93
Mode	13,48	3,00	148,00	158,93
Standard deviation	35,62	40,41	77,07	246,07
Variance	1268,59	1633,32	5939,74	60550,61
Skewness	4,51	3,08	0,74	2,25
Kurtosis	35,95	14,68	0,96	5,89

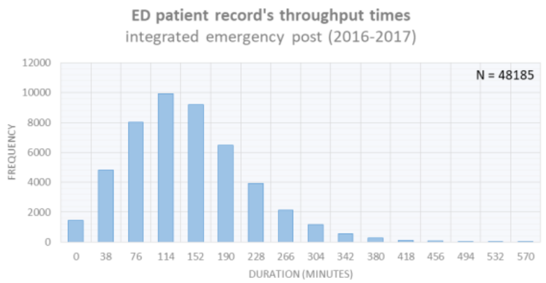
Table 37: Descriptive statistics of the actual and simulated patients' LOS distributions for both the GP post and the ED during the integrated emergency care organization. The simulation model developed by Koster (2014) is used, while the input variables are originating from in between 2016-2017.



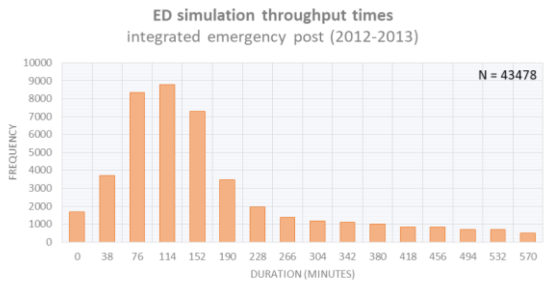
a) Patient record's length of stay GP post physical consults.



b) Simulated length of stay GP post physical consults.



c) Patient record's length of stay ED.



d) Simulated length of stay ED.

Figure 53: The actual and simulated patient's LOS distributions obtained from the IEP Enschede in between 2016-2017. The simulation model developed by Koster (2014) is used. The patients used for the GP post LOS calculations also include telephonic consults (care pathway A9).

Over the years, the actual number of patient arrivals for both the GP post and the ED decreased, as observed in Figure 51. If today's patient arrivals would be equal to the number of patient arrivals in between 2012 and 2013, a significant increase in the patients' LOS would be obtained for both the GP post and the ED (Table 37). The simulated GP post LOS is 10.3% higher in comparison with the actual GP post LOS for 2016 and 2017. The patient arrivals of 2012 and 2013 do affect the integrated GP post more in comparison with the separated emergency care organization (Table 36), because more self-arrivals will require medical care unannounced. Simulated patients will be invited sooner for a physical consult at the GP during the integrated organization, but the average waiting time simulated at the GP post itself will increase from 19 minutes up to 28 minutes. All GP post staff members will experience a workload increase. The LOS increase is slightly tempered because the NP is allocated more often, which reduces the GPs' utilization rate a little bit.

The ED LOS simulated is 57.9% too high in comparison with the actual ED LOS observed. The self-referrals do not arrive at the ED anymore during the out-of-hours emergency care. However, the patient records of 2012 and 2013 include more GP post patient arrivals, which forwards more patients to the ED in the simulation model. Koster assumed that all GP post referrals are labeled, which increases the residents' workload even further in comparison with the separated organization. Only the internal medicine residents experience less workload, because these patients are more externally referred. The waiting times before anamnesis are almost three times higher in comparison with the actual LOS values observed in between 2016 and 2017. Also the waiting times before the actual treatments increased from 49 minutes in 2016 and 2017 up to 1 hour and 18 minutes, if the number of patient arrivals is equal to the distributions found in between 2012 and 2013.

7.6. Separated versus integrated (2016-2017)

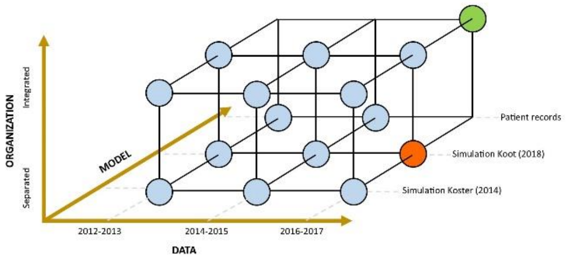


Figure 54: Relevant research model components.

7.6.1. Solution validation components

The previous sections revealed that the patient arrivals, processes and resource allocations changed significantly for both the GP post and the ED. Therefore, it cannot be concluded yet what the effects of the integration itself are. However, more insight into the actual effects of the integration can be obtained by simulating the separated emergency care, including the input variables obtained from for 2016 and 2017 (Figure 54).

7.6.2 Data modifications

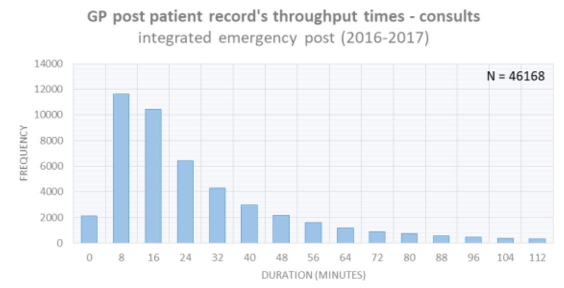
Most of today's input variables will remain unchanged, only the type and number of patient arrivals require some modifications. If patients are free once again to contact the ED by themselves, the GP post's patient population will decrease by 7.25%. The ratio of self-referrals visiting the ED will increase to 12% of the total ED patient population. This will result in different care path allocations for the patients contacting the IEP, the exact data modifications are fully explained in Appendix V.

7.6.3. Simulation results – separated versus integrated (2016-2017)

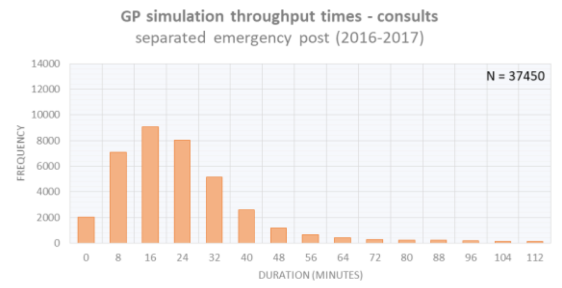
The distribution statistics of both the GP post LOS and ED LOS are given in Table 38, while the corresponding distributions are visualized in Figure 55. The simulation's waiting times and utilization rates are visualized in Appendix S. The results are compared to the actual LOS values obtained from the integrated emergency organization in between 2016 and 2017. Note that the difference in patient arrivals is very close to the 6899 patient transferred from the GP post to the ED. It becomes very clear that the GP post LOS decreases, while the ED LOS increases due to the increase in arriving patients.

Statistic	LOS GP post		LOS ED	
Simulation model Koot 2018	Patient records integrated 2016-2017	Simulation model separated 2016-2017	Patient records integrated 2016-2017	Simulation model separated 2016-2017
Number	40989	37810	48226	52542
Mean	33,77	28,82	159,38	178,07
Median	22,75	24,60	151,00	166,02
Mode	13,48	3,00	140,00	181,15
Standard deviation	35,62	20,83	79,97	89,82
Variance	1268,59	433,98	6395,20	8068,30
Skewness	4,51	2,77	1,40	1,91
Kurtosis	35,95	11,73	8,90	7,72

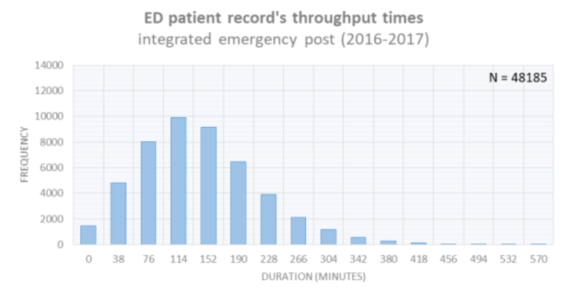
Table 38: Descriptive statistics of the actual and simulated patients' LOS distributions for both the GP separated post and the ED in between 2016 and 2017. The simulation model developed by Koot (2018) is used to determine the performances of the separated emergency care organization, while the input variables are originating from in between 2016-2017.



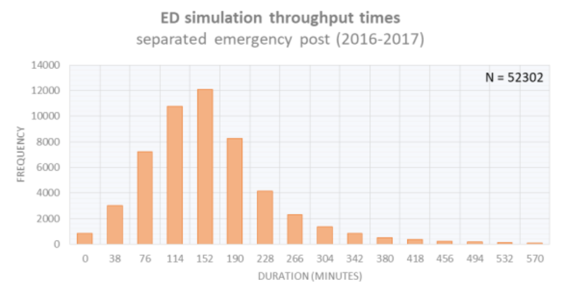
a) Patient record's GP post LOS – integrated (2016-2017)



b) Simulated GP post LOS – separated (2016-2017).



c) Patient record's ED LOS - integrated (2016-2017)



d) Simulated ED LOS – separated (2016-2017)

Figure 55: The actual and simulated patient's LOS distributions obtained for both the separated GP post and the ED in between 2016 and 2017. The simulation model developed by Koot (2018) is used. The patients used for the GP post LOS calculations also include telephonic consults (care pathway A9).

The number of self-referrals decreases for the GP post during the separated emergency care organization, which results into lower workloads for all GP post staff members. The utilization rate of the physical triage nurse is strongly reduced from 20.0% down to 7.2%. The lower utilization rates result into shorter waiting times for almost all activities. On the other hand, the ED LOS increase can be explained by the increase in the utilization rates of both the emergency physicians and surgery/orthopedic residents, which is equal to 65.5% and 60.8% respectively. During the integrated emergency organization, these staff members included an average utilization rate of just 49.0% and 53.8%. The higher utilization rate of these bottleneck resources result into more waiting times for the ED patients. The opposite is true for the GP post, but the effect is of less influence (the GPs' average utilization rate decreased from 49.4% down to 46.5%).The results become even clearer if the LOS values are separated for each urgency classification.

7.7. The impact of each solution validation component

All the comparisons in the customized solution validation framework are evaluated in the previous sections. The insights gained makes it possible to determine the effects of each main component. The following subsections will discuss the impact of: 1) the data modifications; 2) the model modifications and 3) the configurations recommended.

7.7.1. Impact of data modifications

The type and number of patient arrivals changed significantly over the years, which means that the KPIs are strongly influenced if the patient records from 2012 and 2013 are used to assign values to the new simulation model's input variables. The number of GP post patients arriving today is lower in comparison with 2012 and 2013. It was expected that more patients at the GP post would result into higher GP post LOS values, especially if the increased activity durations are taken into account. The GP post LOS simulated did not increase that much however, the patients only had to wait longer at home for their appointment. These unexpected modifications can be explained by the high frequency of calling patients. The appointment strategy allows the GP assistants to schedule the arriving patients smartly, resulting into a slight GP post LOS increase while the GP utilization rate is relatively high. The number of ED arrivals remained relatively the same in between 2012 and 2017, but the type of patient arrivals changed significantly. More patients are referred from the GP post to the ED for a second consult, which increases the workload of the staff members that already face high utilization rates. Therefore, it can be concluded that the ED LOS is mainly affected by the type of patient arrivals due to the changing resource allocations. The number of diagnostic test requests decreased, but the average durations increased. The ED can reduce its average LOS by removing out-of-hours self-referrals, but these effects are counterproductive if the number of GP post referrals is not controlled.

7.7.2. Impact of model modifications

The actual and simulated LOS values differ significantly for both the GP post and the ED. The implementation of today's input variables into the simulation model made by Koster (2014) did not result into a proper representation of the system's actual behavior. The conceptual model should be expended to gain reliable simulation results. The GP post LOS is clearly overestimated by Koster's simulation model for both the separated (2014-2015) and integrated organization (2016-2017), the values are almost doubled in comparison with the patient records' values. This is mainly due to the simplified appointment strategy that invites patients too early, because the actual workload is not taken into account. The staff allocations are also not correctly simulated, resulting into too high utilization rates for the GP post's staff members. The decision logic covering patient visits at home is also incorrectly implemented. The ED LOS simulated was approximately 38% less in comparison with the actual ED LOS for both the separated (2014-2015) and integrated (2016-2017) emergency organization. The simulated ED patients left the system too early due to incorrect staff allocations. It is not possible to allow a type of staff member to leave the ED completely, otherwise patients would have to wait half a day until the staff's next shift begins. Koster's simulation model cannot not anticipate to these types of problems, the issues can only be solved by assuming infinite staff availability or implementing some new decision logic.

7.7.3. Impact of configurations recommended

It can be concluded that the ED benefits most from the integration. The transfer of self-referrals to the GP post allowed the emergency physicians to decrease their workload by approximately 10% on average, which decreases the average ED LOS by 16%. The GP post however has to take care of more unexpected patient arrivals, which increases the average GP post LOS. The GP post is able to take care of the workload increase more efficient, because of the ability to schedule calling patients smartly. The average GP post LOS decreases with 16% if the two organizations would still be separated today, while the ED LOS increases by 12%, especially for the low-urgent patients. The arrival of more self-referrals also changed the ratio of urgency classifications allocated within the ED. Therefore, it can be concluded that the implementation of the IEP Enschede reduced the ED's workload by replacing approximately 12% of the total ED population to the GP post. The integration allows the ED LOS to decrease. However, the workload is transferred to the GP post, which experienced an increase in its workload and LOS.

7.7.4. Evaluating recommendations made by Koster (2014)

Koster (2014) expected that the IEP implementation would result in higher LOS values for the GP post and the ED. Therefore, Koster recommended to integrate the GP post and the ED in combination with other organizational changes to provide better LOS results. The solution validation in this chapter partly confirms the recommendations made by Koster. The decision to integrate will reduce the ED LOS by 12% approximately, but the GP post LOS increased by 16% due to the increased number of self-referrals arriving. These changes are acceptable for two reasons:

1. The GP post LOS is absolutely smaller than the ED LOS (≈34 versus ≈161 minutes respectively);
2. The GP post's appointment strategy allows the GP assistants to schedule arriving patients smartly, reducing the negative impact that self-referrals have on the GP post LOS.

Koster did not expect that the ED LOS would be reduced due to the integration only, but new process descriptions allow the ED's staff to take care of GP post referrals quicker. The solution validation in this chapter also revealed both past and current bottlenecks in the IEP's processes. Closer examination of these bottlenecks showed that the other recommendations made by Koster (2014) are still valid today:

1. The GP post LOS is mainly influenced by the GP's high utilization, resulting in high waiting times for physical consults, telephonic consults and patient visits at home. Koster's recommendation to use an additional NP at the GP post could help to reduce the GPs workload;
2. The ED LOS is mainly influenced by the high utilization of emergency physicians and surgery/orthopedic residents. Koster's recommendation to treat both unlabeled and labeled patients partly relaxes the residents' workload, but does not solve the high waiting times of unlabeled ED patients;
3. Koster recommended that both organizations should make use of the same triage system, which makes the ED triage activity unnecessarily. This recommendation does not solve one of the bottlenecks identified, but reduces the ED LOS by removing an activity from the patients' care pathways.

7.8. Solution validation conclusions

In this chapter, a solution validation study is executed to gain insights into the performances of both the separated and integrated emergency care organization in Enschede from 2012 up till 2017. The impact of three types of modifications are investigated in more detail: 1) the data modifications; 2) the model modifications and 3) the configurations recommended. The alternative comparisons made are visualized by the customized solution validation framework in Figure 44. The resulting GP post and ED LOS values are visualized in Figure 56 and Figure 57 respectively for all comparisons made.

It can be concluded that both the actual GP post LOS and the ED LOS increased over the years. The increases are partly explained by the decision to integrate the GP post and the ED, but the changes are also affected by the changing values of the input variables taken into consideration. Especially the type and number of patient arrivals changed significantly over the years. The simulation model developed by Koster (2014) does not govern all the required elements to simulate the separated (2014-2015) and integrated (2016-2017) emergency organization properly. The conceptual model should be expended in order to gain reliable simulation results.

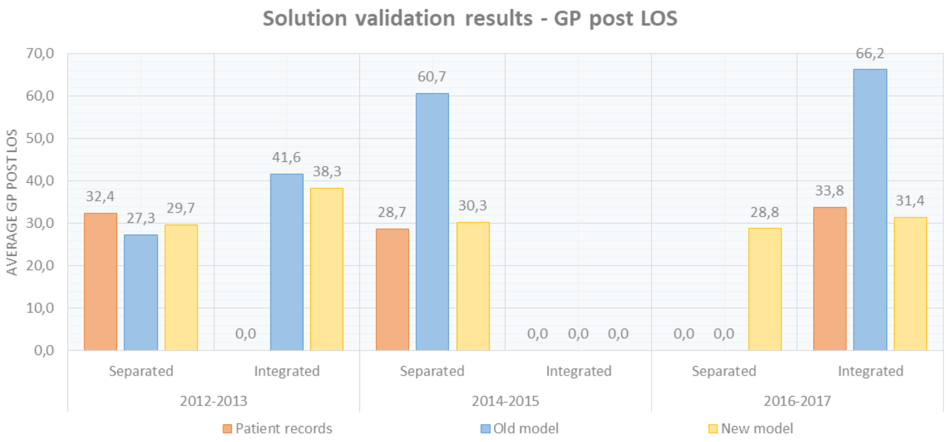


Figure 56: Solution validation GP post LOS results, separated for each model, data set and organization type used.

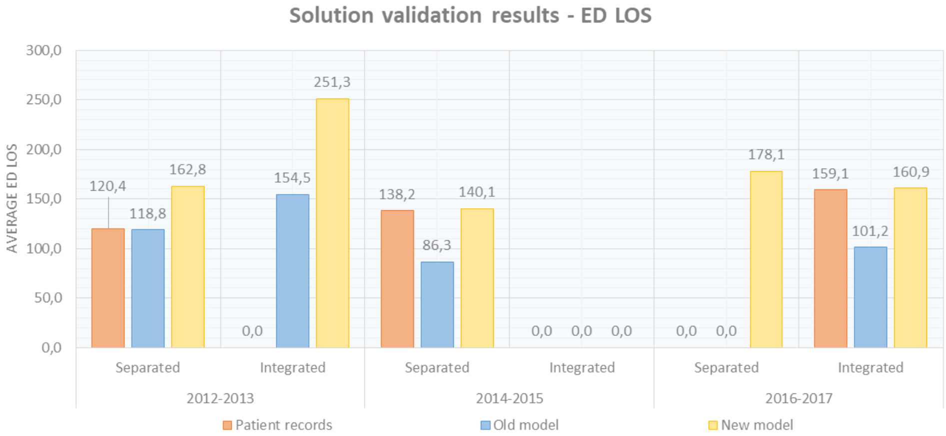


Figure 57: Solution validation ED LOS results, separated for each model, data set and organization type used.

The solution validation enables the stakeholders to understand how their operations actually work. The necessity to validate the simulation results makes it possible to see which new configurations have been implemented over time. Comparing the expected and actual IEP performances enables the decision makers to alter their future plans, allowing to construct new experiments. New experiments will be generated and evaluated in Chapter 8.

Chapter 8 – Experimentation

The solution validation in chapter 7 revealed the performances of the separated and integrated emergency care organizations for different periods. The comparison of simulation results, patient records and decision logic made it possible to identify the system's bottlenecks in more detail. The main focus of this chapter is to improve the IEP's logistic performances by taking down each of these bottlenecks found. Therefore, an answer will be found for research question 7.

Research question 7: Which organizational configurations will optimize the out-of-hours care within the integrated emergency post of Enschede?

First, the input and output variables used to optimize the IEP organization will be discussed. Second, the experimental design will be discussed in more detail, including the type of simulation, warm-up period, number of replications and experimental factors. Finally, the simulation results will be evaluated in order to find the best set of configurations.

8.1. Experiment objectives

The main aim of this chapter is to improve the IEP's logistic performances based on the insights gained during the solution validation. The new simulation model resulted to be valid in order to simulate the today's IEP processes, which can therefore be used to evaluate alternative configurations. The GP post LOS has mainly increased due to the increase in self-referrals and activity durations. Therefore, a solution should be found that will reduce the GP post's workload in order to maintain the organization's flexibility. The ED LOS is positively influenced by the integration, but the changing type of patient arrivals increased the workload of the most occupied staff members. New experiments should be defined to improve the GP post's and ED's performances simultaneously.

8.2. Experimental factors

The simulation model is based on the data set corresponding to the integrated emergency organization in 2016 and 2017, including the type and number of patient arrivals, the care pathway allocations, the activity durations and the resource allocations. A total of twelve experimental factors are constructed to find an alternative configuration of the IEP Enschede. The experimental factors are clustered in three classes, corresponding to the type of organization for which the alternative configuration applies. Thirteen experimental factors are developed for both the GP post and the ED separately, but some experimental factors apply to both organizations.

GP post experimental factors:

1. Different appointment strategy
    a. Alternative slot durations;
    b. Different number of patient invitations allowed per appointment slot;
    c. Alternative priority rules given to the patient's appointment based on their urgency;
2. The allocation of a dedicated staff member for patient visits at home;
3. Alternative staff rosters for the GPs;
    a. One additional GP in the evening shift from 5:00pm to 0:00am;
    b. One less GP in the night shift from 0:00am to 8:00am.
4. Creating a patient buffer before the GP starts visiting patients at home.

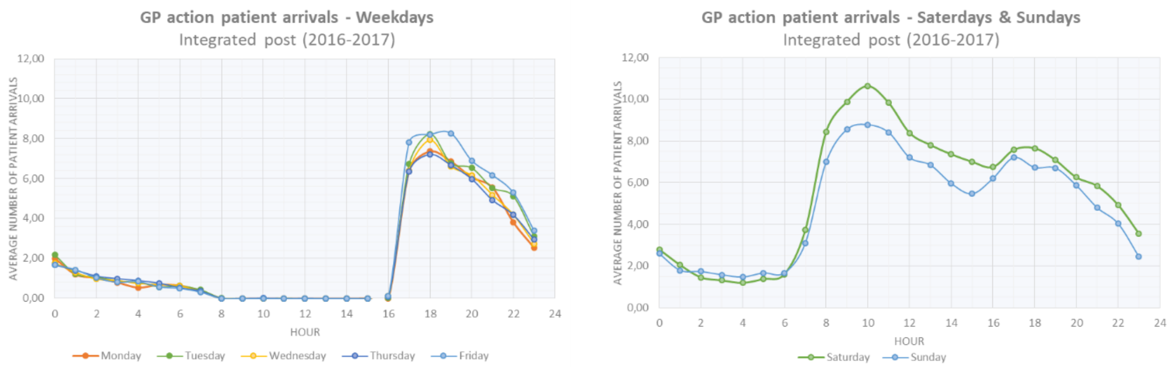
ED experimental factors:

5. Alternative staff roster for:
    a. The emergency physicians;
    b. The residents of all treatment groups available at the ED;
6. The possibility to expand the emergency physicians' authorities to treat all patients;
7. The possibility to execute the triage activity in the patient's treatment room;
8. The possibility to admit patients directly into the hospital without any waiting time;
9. The possibility to access the medical specialist immediately, without any waiting time.

IEP experimental factors:

10. The possibility to share the triage results between the GP post and the ED;
11. The possibility to make use of each other's treatment rooms;
12. Different responsibilities for the triage of all self-referrals contacting the IEP Enschede.
    a. Only GP post staff execute the physical triage of self-referrals;
    b. Only ED staff execute the physical triage of self-referrals.

The motivation to include these experimental factors are fully described in Appendix W, including the variables' ranges and comparisons to previous simulation researches made by Borman (2012) and Koster (2014). Note that most experimental factors do not include the decision to hire more staff members to increase capacity, it should be examined first if the existing capacity can be allocated more efficient and effective. The GP post and ED stakeholders indicated that it is hard to find new staff members for today's organization, an increase in capacity would be too costly. Therefore, alternative staff rosters are made based on the actual staff requests made per hour. The hourly arrival rates are visualized first and the rosters are based secondly. An example is given in Figure 58 for the hourly number of patients requesting a GP, all other graphs are given in Appendix X.



a) Average week arrivals *b) Average week arrivals*

Figure 58: GP post patient arrivals, requesting a type of treatment given by a GP.

8.3. Experimental design

In this section, the simulation configurations will be discussed in order to obtain reliable results. The type of simulation will be discussed to determine the warm-up length and the number of replications required. The experimental settings will be explained after that.

8.3.1. The type of simulation

The IEP Enschede consists of two different organization. The GP post is only operational during the out-of-office hours, while the ED is opened 24/7. Therefore, two alternative simulation systems can be identified. The GP post can be represented as a terminating system due to the "natural" event that specifies the length of each replication (Law, 2007). The ED can be described as a non-terminating simulation with steady-state cycle parameters. Patients can always arrive at the ED, but the frequency depends on the patient's arrival rate. The arrival pattern is repeated for every week.

The ED allows the IEP Enschede to be open 24/7, which ensures that patients can always arrive in order to be treated. Therefore, it was expected that the IEP Enschede would include a steady-state system including cycle parameters. However, the patient arrivals at night are relatively low, resulting into a high probability that the system is empty at the end of the day. Therefore, the IEP Enschede is considered as a terminating simulation in which the arrival pattern is repeated every week.

8.3.2. Output variables

The patients' LOS values resulted to be affected the most over the years. Therefore, it is reasonable to investigate the configuration's effects on the LOS values simulated. The patients' LOS values are separated into three main categories:

1. **LOS entrance**: the time before physical entering the IEP Enschede physically;
2. **LOS GP post**: the waiting times and consult durations within the GP post;
3. **LOS ED**: the waiting times and consult durations within the ED.

The LOS values are also aggregated into one LOS statistic, which represents the average difference between the patient's arrival and its final treatment. Therefore, the LOS values both indicate the waiting times and activity durations in one statistic. The resources' utilization rates are also important to take into account. The utilizations can either indicate why the LOS values increase/decrease or identify the flexibility remaining for further expansion. Finally, the patient's service statistics are evaluated for both organizations, which measure the number of patients that waited too long for their first contact moment.

8.3.3. Warm-up period

No warm-up calculations are required, because no steady state exists for a terminating simulation. However, the first week simulated is removed from the simulation in order to make sure no startup issues are included in the simulation results.

8.3.4. Replications

Multiple replications for each configuration are required in order to obtain reliable confidence intervals of the LOS values simulated. One replication is represented by the simulation of one week. The sequential procedure proposed by Law (2007) is applied in order to obtain an estimate of the LOS values with a relative error of ϒ (0<ϒ<1) and a confidence interval of 100*(1-α)%. First, the LOS values of two simulated replications will be used to determine the relative error approximately by using the formula in equation 8.1. If the relative error is too large, a new replication will be added.

Equation 8.1: Number of replications

$$n_r^*(\gamma) = \min\left\{ i \geq n : \frac{t_{i-1,1-\frac{\alpha}{2}}\sqrt{\frac{S^2(n)}{i}}}{|\bar{X}(n)|} \leq \frac{\gamma}{1+\gamma} \right\}$$

The application of equation 8.1 and the sequential procedure revealed that different number of replications are required to model each LOS statistic with 95% confidence (*Table 39*). Seven replications are made if the experimental factors correspond to both the GP post and ED, while a total of 37 or five replications is used respectively if the GP post or ED is investigated individually.

	Total LOS	LOS GP post	LOS ED
#Replications (95% confidence)	7	37	5

Table 39: The number of replications required to simulate each KPI with 95% confidence intervals. The number of replications are obtained via the sequential procedure proposed by Law (2007).

8.3.5. Experiment configurations

A total of 4,055,040 experiments will be generated if a multi-level experimental design is used to simulate all experimental factors' values. The simulation model requires approximately 5 seconds to simulate one week. Therefore, if 37 replications are taken into account for each experiment, the total simulation run length would take 8,682 days (almost 24 years). A smart experimental design required in order to obtain useful simulation results in manageable time. Therefore, the experiment configurations are separated into four different categories:

1. **Single experiments:** first the effect of all experimental factors will be investigated separately. One experimental factor is changed at a time, while all other variable values are kept the same as observed in today's practices. The alternative variable value is changed back once the new experiment is initiated. The experimental factor is only used for further experimentation if a LOS improvement is obtained during the single experiment phase. Therefore, this step is mainly used to decrease the number of experimental factors;
2. **2^k factorial design GP post:** the average change in the GP post LOS is observed by simulating only two levels of each GP post and IEP experimental factor;
3. **2^k factorial design ED:** the average change in the ED LOS is observed by simulating only two levels of each ED and IEP experimental factor;
4. **Appointment multi-level experiment:** the GP post appointment strategy depends on three factors, resulting in 64 alternative experiments only. The simulation time required for these configurations remains sufficient and are therefore fully simulated in order to gain insight into the best appointment strategy;
5. **Multi-level experiment:** the solution space corresponding to the best performing experimental factors are completely enumerated. The first for experiment configurations are used to gain insight into the most promising factors and to reduce the total solution space.

Only the main- and two-way interaction effects are investigated for both the GP post and ED 2^K factorial design. A 95% confidence interval (95% CI) is constructed for the expected main- and two-way interaction effects. Therefore, the equations for the average effect (equation 8.2), the effect's variance (equation 8.3) and the actual 95% CI formula (equation 8.4) are required. Note that the main effects will represent the average change in response if the factors' value is increased from its lower value to its upper value. The two-way interaction effect represent the average effect of one intervention, given that a second intervention is also used.

Equation 8.2: average effect	$\bar{e}_j(n) = \frac{\sum_{i=1}^{n} e_j^i}{n}$	$\forall j$
Equation 8.3: effect's variance	$S_j^2(n) = \frac{\sum_{i=1}^{n}\left[e_j^i - \bar{e}_j(n)\right]^2}{n-1}$	$\forall j$
Equation 8.4: 100*(1-α)% CI	$CI = \bar{e}_j(n) \pm t_{n-1,1-\frac{\alpha}{2}} \sqrt{\frac{S_j^2(n)}{n}}$	$\forall j$

The j^{th} replicated effect of input variable i is represented by e_j^i. The average effect is given by $\bar{e}_j(n)\ \forall j$ for all n replications, while the variance is represented by $S_j^2(n)$. The critical value corresponding to the t-distribution is given by $t_{n-1,1-\frac{\alpha}{2}}$. The expected main effects and two-way interactions are significant if the corresponding 95% CI does not contain the zero value.

8.4. Experiment results

8.4.1. Single experiment values

The simulation results for the GP post, ED and IEP experimental factors are represented in Table 40, Table 41 and Table 42 respectively. All LOS values are marked by a color in order to visualize the differences with today's performances. Green marked LOS values indicate a decrease of the LOS for that experiment, while red marked LOS values indicate an increase. The utilization and service KPIs are also color marked, but now the green marked KPI values indicate an increase in comparison with the actual KPI value of today's organization.

GP post experimental factors		Simulation KPIs				
Experimental factor	Value	LOS total	LOS entrance	LOS GP post	GP utilization	GP service
Original settings	*-*	*01:23:44*	*00:23:18*	*00:33:41*	*35,8%*	*96,9%*
Appointment slot duration	00:05:00	01:22:13	00:19:23	00:36:40	35,9%	99,1%
	00:06:00	01:22:13	00:19:47	00:36:08	35,8%	98,8%
	00:07:00	01:22:07	00:20:11	00:35:17	35,8%	98,7%
	00:08:00	01:22:58	00:21:04	00:35:38	35,9%	98,4%
	00:09:00	01:23:24	00:22:06	00:34:51	35,9%	97,6%
	00:10:00	01:23:44	00:23:18	00:33:41	35,8%	96,9%
	00:11:00	01:24:24	00:24:58	00:32:01	35,7%	96,0%
	00:12:00	01:25:20	00:26:38	00:31:06	35,9%	95,3%
	00:13:00	01:26:32	00:29:22	00:29:52	35,7%	94,0%
	00:14:00	01:28:03	00:31:55	00:29:07	35,9%	92,6%
	00:15:00	01:29:23	00:34:27	00:28:11	35,8%	91,2%
Appointment patient frequency	3	01:22:45	00:20:11	00:36:33	35,9%	99,1%
	4	01:22:30	00:20:10	00:36:15	35,8%	99,0%
Appointment urgency prioritization	U1-U2	01:22:53	00:21:39	00:34:59	35,8%	98,8%
	U1-U3	01:22:36	00:20:18	00:36:13	35,8%	99,2%
	U1-U4	01:22:23	00:20:07	00:35:50	35,8%	99,2%
	U1-U5	01:22:30	00:20:10	00:36:15	35,8%	99,0%
Dedicated patient visits	TRUE	01:19:20	00:21:13	00:25:00	33,1%	98,2%
New GP rosters	Evening +1	01:19:05	00:18:19	00:24:05	33,8%	99,5%
	Night -1	01:26:58	00:24:00	00:36:20	38,9%	95,8%
Patient visit buffer	2	01:27:36	00:27:15	00:30:54	34,7%	95,3%
	3	01:29:36	00:30:13	00:30:27	34,5%	93,0%

Table 40: Single GP post experiment results. Green marked LOS values indicate a decrease of the LOS for that experiment, while red marked LOS values indicate an increase. The color marks are made for each experimental factor individually.

The GP post's appointment strategy factors include a clear tradeoff between the LOS entrance and the LOS GP post (Table 40). If more patients are invited to the GP post, the entrance LOS and the service KPI are improved, but the GP post LOS increases significantly. Reducing the number of GPs present during the night increased the LOS by 3:00 minutes, while the service level is reduced by 1%. Therefore, it is possible to reduce waiting times by implementing alternative staff allocations like the dedicated driver or new evening shifts, because capacity could be made available by removing one night shift. The patient buffer in front of the GP visits results into a decrease of the patients' waiting time at the GP post itself, but the service level decreases due to late arrivals at the patient's homes. All GP post experimental factors except for the altered night shift resulted into the improvement of at least one KPI, all these factors will be included in the 2^K factor analysis in Section 8.4.2.

ED experimental factors		Simulation KPIs			
Experimental factor	Value	LOS total	LOS ED	ED utilization	ED service
Original settings	*-*	*01:23:44*	*02:38:12*	*29,1%*	*91,7%*
New ED staff rosters	ED doctor	01:20:57	02:30:34	27,2%	91,9%
	RES1	01:18:59	02:25:03	27,7%	92,0%
	RES2	01:24:17	02:40:02	29,5%	91,5%
	RES3	01:23:22	02:37:34	28,3%	91,6%
	RES4	01:23:34	02:37:25	28,3%	91,9%
Increase authority ED doctor	TRUE	01:23:15	02:37:30	29,4%	91,7%
Triage in treatment room	TRUE	01:22:43	02:35:30	29,2%	92,4%
Direct hospital admission	TRUE	01:16:10	02:16:24	29,1%	91,9%
Medical specialist availability	TRUE	01:23:03	02:35:35	29,1%	91,7%

Table 41: Single ED experiment results. Green marked LOS values indicate a decrease of the LOS for that experiment, while red marked LOS values indicate an increase. The color marks are made for each experimental factor individually.

The early hospital admission provide the best improvement simulated for the ED, because the ED LOS can be reduced by 22:00 minutes approximately (Table 41). The modified staff rosters for both the emergency physician and the surgeon/orthopedic residents result into a significant improvement of the ED LOS by 8:00 and 13:00 minutes respectively. The decision to perform the triage activity also seems to improve the ED LOS slightly, the same is observed for the increased availability of medical specialists. The staff rosters for all other residents do not result into a significant LOS improvement and are therefore excluded from the 2^K factor analysis in Section 8.4.3.

IEP experimental factors		Simulation KPIs							
Experimental factor	Value	LOS total	LOS entrance	LOS GP post	LOS ED	GP utilization	ED utilization	GP service	ED service
Original settings	*-*	*01:23:44*	*00:23:18*	*00:33:41*	*02:38:12*	*35,8%*	*29,1%*	*96,9%*	*91,7%*
Collaborated triage	TRUE	01:22:43	00:23:26	00:33:37	02:35:06	35,9%	27,8%	97,0%	93,6%
Room sharing	TRUE	01:23:44	00:23:23	00:33:46	02:38:03	35,8%	29,1%	96,9%	91,9%
Physical triage responsibility	GP post only	01:23:29	00:23:15	00:32:59	02:38:16	36,0%	28,9%	97,1%	91,9%
	ED only	01:23:36	00:23:20	00:33:35	02:37:52	34,5%	29,6%	97,0%	91,9%

Table 42: Single IEP experiment results. Green marked LOS values indicate a decrease of the LOS for that experiment, while red marked LOS values indicate an increase. The color marks are made for each experimental factor individually.

The LOS improvements resulting from the IEP experimental factors in Table 42 are not significant. Only the decision to collaborate for the triage activity seems to improve the ED LOS a little bit. Therefore, the triage collaboration is only included in the 2^K factor analysis of both Section 8.4.2 and Section 8.4.3, the other experimental factors are not taken into consideration.

8.4.2. 2^K Factorial design – GP post

The first 2^K factor analysis is conducted for all GP post experimental factors described in Section 8.3, plus the triage collaboration which applies to both the GP post and the ED. Therefore, seven experimental factors are taken into consideration for the GP post's 2^K factor analysis:

1. Factor 1: Appointment slot duration (low value=7:00; high value=13:00);
2. Factor 2: Appointment patient frequency (low value=0.5; high value=0.75);
3. Factor 3: Appointment urgency priority (low value=U1 only; high value=U1-U55);
4. Factor 4: Triage collaboration (low value= FALSE; high value=TRUE);
5. Factor 5: Dedicated GP visit (low value= FALSE; high value=TRUE);
6. Factor 6: New GP staff roster (low value= FALSE; high value=TRUE);
7. Factor 7: Patient buffer GP visit (low value= 1; high value=3);

The 95%-CI for the main- and two-way interaction effects are given in Table 43 for both the Entrance LOS and GP post LOS, the corresponding visualizations are given in Figure 59 and Figure 60 respectively.

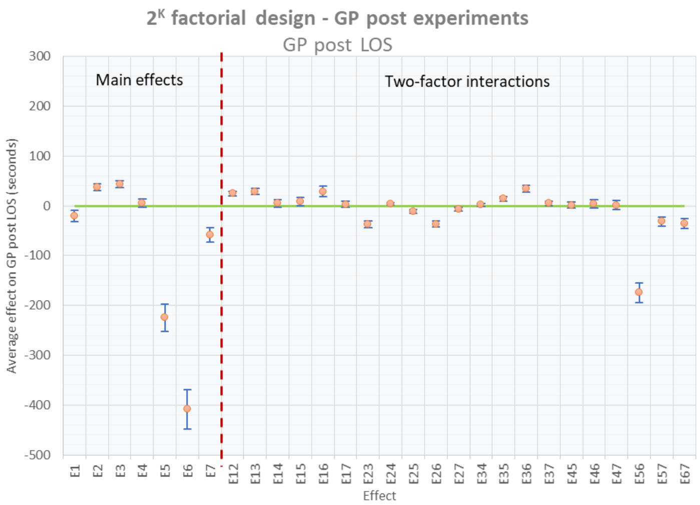


Figure 59: Experimental design plots, including the main effects and two-factor interactions for the entrance LOS.

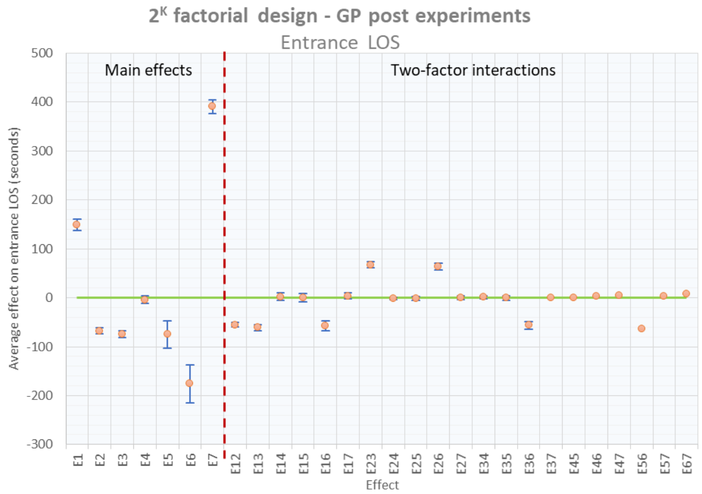


Figure 60: Experimental design plots, including the main effects and two-factor interactions for the GP post LOS.

Experiments			Entrance LOS					GP post LOS				
Type of effect	Effect ID	Effect description	95% confidence interval				Statistically significant?	95% confidence interval				Statistically significant?
Main effects	E1	Appointment slot duration	↓	149,41	+/-	11,18	TRUE	↑	-20,56	+/-	11,46	TRUE
	E2	Appointment patient frequency	↑	-67,56	+/-	8,02	TRUE	↓	37,23	+/-	6,41	TRUE
	E3	Appointment urgency priority	↑	-74,24	+/-	8,73	TRUE	↓	43,72	+/-	6,77	TRUE
	E4	Triage collaboration	→	-3,85	+/-	4,57	FALSE	→	5,13	+/-	7,87	FALSE
	E5	Dedicated GP visit	↑	-74,78	+/-	11,97	TRUE	↑	-224,47	+/-	27,64	TRUE
	E6	New GP staff roster	↑	-175,99	+/-	18,79	TRUE	↑	-408,59	+/-	39,17	TRUE
	E7	Patient buffer GP visit	↓	390,54	+/-	25,28	TRUE	↑	-58,77	+/-	14,05	TRUE
Two-way interaction effects	E12	E1+E2	↑	-55,03	+/-	6,55	TRUE	↓	24,93	+/-	4,65	TRUE
	E13	E1+E3	↑	-60,98	+/-	6,91	TRUE	↓	28,80	+/-	6,42	TRUE
	E14	E1+E4	→	2,07	+/-	6,89	FALSE	→	4,68	+/-	7,94	FALSE
	E15	E1+E5	→	-0,16	+/-	3,97	FALSE	↓	8,49	+/-	8,37	TRUE
	E16	E1+E6	↑	-57,10	+/-	10,11	TRUE	↓	28,30	+/-	10,59	TRUE
	E17	E1+E7	→	3,65	+/-	4,28	FALSE	→	3,00	+/-	6,43	FALSE
	E23	E2+E3	↓	67,56	+/-	8,02	TRUE	↑	-37,23	+/-	6,41	TRUE
	E24	E2+E4	→	-0,94	+/-	2,29	FALSE	↓	3,62	+/-	2,56	TRUE
	E25	E2+E5	→	-1,23	+/-	2,44	FALSE	↑	-10,68	+/-	3,80	TRUE
	E26	E2+E6	↓	63,64	+/-	7,59	TRUE	↑	-36,68	+/-	6,53	TRUE
	E27	E2+E7	→	0,21	+/-	2,36	FALSE	↑	-6,49	+/-	3,40	TRUE
	E34	E3+E4	→	1,12	+/-	3,14	FALSE	→	1,68	+/-	3,32	FALSE
	E35	E3+E5	→	-0,42	+/-	3,12	FALSE	↓	14,11	+/-	4,72	TRUE
	E36	E3+E6	↑	-56,50	+/-	7,58	TRUE	↓	33,96	+/-	7,16	TRUE
	E37	E3+E7	→	0,76	+/-	2,77	FALSE	↓	3,62	+/-	4,51	TRUE
	E45	E4+E5	→	0,62	+/-	4,40	FALSE	→	1,16	+/-	6,37	FALSE
	E46	E4+E6	→	3,15	+/-	4,09	FALSE	→	3,87	+/-	7,67	FALSE
	E47	E4+E7	↓	4,49	+/-	4,33	TRUE	→	1,44	+/-	9,15	FALSE
	E56	E5+E6	↑	-62,85	+/-	10,78	TRUE	↑	-174,64	+/-	19,88	TRUE
	E57	E5+E7	→	3,18	+/-	5,25	FALSE	↑	-31,61	+/-	8,71	TRUE
	E67	E6+E7	↓	7,26	+/-	5,91	TRUE	↑	-35,98	+/-	10,01	TRUE

Table 43: 95% CI for the average main- and two-way interaction effects of both the Entrance LOS and the GP post LOS. Green arrows visualize the experimental factors that result into a significant LOS decrease, while red arrows mark a significant LOS increase. Yellow arrows represent the factors that do not result into a significant LOS modification.

The implementation of new GP staff rosters will improve the GP post LOS significantly by 2:25 minutes (-11%). A reduction of the GP post LOS by 5:40 minutes (-17%) is obtained if a new staff member is dedicated to patient visits only The implementation of a patient buffer in front of GP visits reduces the GP post LOS by 58 seconds (-3%). More collaboration between the GP post and the ED during the triage activity does not result into a significant change of both the entrance LOS and the GP post LOS, even not in combination with another experimental factor. The altered GP staff roster seems to result in an additional LOS improvement in combination with the implementation of a dedicated staff member for patient visits at home (two-way interaction effect E56).

The GP post LOS interaction effects in Figure 59 are relatively small, indicating that most experimental factors can be implemented independently from each other to obtain a LOS improvement. The interaction effect is only very low if more capacity is added simultaneously (experiment factor 5 and 6 for example), which means that even better results are expected if multiple staff allocations are renewed. The interaction effects corresponding to the Entrance LOS in Figure 60 represent the same type of behavior, but these effects are mostly not 95% statistically significant. Care should be taken with the alternative appointment strategy, the interaction effects corresponding to experimental factors 2 and 3 indicate that the LOS results can easily be influenced by other experimental factors, both positively and negatively.

8.4.3. 2^K Factorial design – ED

The second 2^K factor analysis is conducted for all GP post experimental factors described in Section 8.3, plus the triage collaboration which applies to both the GP post and the ED. Therefore, seven experimental factors are taken into consideration for the GP post's 2^K factor analysis:

1. Factor 1: Triage collaboration (low value= FALSE; high value=TRUE);
2. Factor 2: Triage in ED treatment room (low value= FALSE; high value=TRUE);
3. Factor 3: New roster ED doctor (low value= FALSE; high value=TRUE);
4. Factor 4: New roster resident 1 (low value= FALSE; high value=TRUE);
5. Factor 5: New roster medical specialist (low value= FALSE; high value=TRUE);
6. Factor 6: Direct hospital admission (low value= FALSE; high value=TRUE);
7. Factor 7: More authority ED doctor (low value= FALSE; high value=TRUE)

The 95%-CI for the main- and two-way interaction effects are given in Table 44 the ED LOS, the corresponding visualization is given in Figure 61.

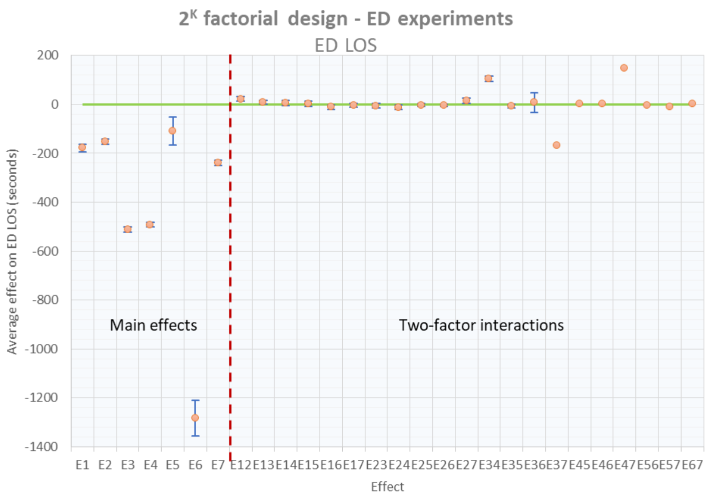


Figure 61: Experimental design plots, including the main effects and two-factor interactions for the ED LOS.

It can be concluded that all individual ED experimental factors result into a significant improvement of the ED LOS. The largest effect is expected by the direct hospital admissions, reducing the ED LOS by 21:23 minutes (-13%). The staff rosters also have great effect on the average ED LOS, the new rosters for the emergency physician would result into an ED los decrease of 8:31 minutes (-5%), while the implementation of a new roster for the surgeon/orthopedic residents would reduce the ED LOS by 8:11 minutes (-5%). The other main effects also result into significant improvements, but with less impact (approximately 1 or 2 minutes LOS reductions on average).

Experiments			ED LOS				
Type of effect	Effect ID	Effect description	95% confidence interval				Statistically significant?
Main effects	E1	Triage collaboration	⇧	-177,46	+/-	38,92	TRUE
	E2	Triage in ED treatment room	⇧	-151,92	+/-	57,57	TRUE
	E3	New roster ED doctor	⇧	-511,05	+/-	177,17	TRUE
	E4	New roster resident 1	⇧	-491,58	+/-	250,04	TRUE
	E5	New roster medical specialist	⇧	-108,31	+/-	24,55	TRUE
	E6	Direct hospital admission	⇧	-1283,48	+/-	67,74	TRUE
	E7	Authorization ED doctor	⇧	-239,96	+/-	111,57	TRUE
Two-way interaction effects	E12	E1+E2	⇨	22,18	+/-	27,76	FALSE
	E13	E1+E3	⇨	8,74	+/-	28,77	FALSE
	E14	E1+E4	⇨	6,63	+/-	14,68	FALSE
	E15	E1+E5	⇨	2,65	+/-	27,79	FALSE
	E16	E1+E6	⇨	-9,69	+/-	17,86	FALSE
	E17	E1+E7	⇨	-2,33	+/-	17,47	FALSE
	E23	E2+E3	⇨	-5,80	+/-	25,25	FALSE
	E24	E2+E4	⇨	-11,69	+/-	30,08	FALSE
	E25	E2+E5	⇨	-1,90	+/-	20,30	FALSE
	E26	E2+E6	⇨	-3,20	+/-	8,32	FALSE
	E27	E2+E7	⇨	15,91	+/-	24,47	FALSE
	E34	E3+E4	⇩	105,07	+/-	57,55	TRUE
	E35	E3+E5	⇨	-6,32	+/-	22,61	FALSE
	E36	E3+E6	⇨	7,51	+/-	14,38	FALSE
	E37	E3+E7	⇧	-168,70	+/-	48,31	TRUE
	E45	E4+E5	⇨	1,98	+/-	37,05	FALSE
	E46	E4+E6	⇨	4,28	+/-	12,71	FALSE
	E47	E4+E7	⇩	148,28	+/-	77,87	TRUE
	E56	E5+E6	⇨	-3,22	+/-	25,30	FALSE
	E57	E5+E7	⇨	-9,62	+/-	10,32	FALSE
	E67	E6+E7	⇨	1,43	+/-	16,43	FALSE

Table 44: 95% CI for the average main- and two-way interaction effects of both the ED LOS. Green arrows visualize the experimental factors that result into a significant LOS decrease, while red arrows mark a significant LOS increase. Yellow arrows represent the factors that do not result into a significant LOS modification.

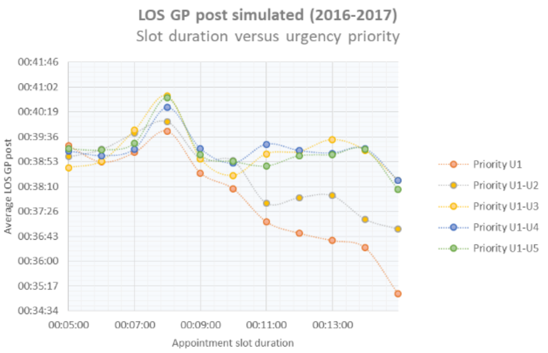
Only three interaction effects include a 95% statistically significant relationship. The expected ED LOS improvements resulting from the new staff rosters for surgery/orthopedic residents are partly opposed if the emergency physicians' authority is increased at the same time. The results are also opposed if new rosters are implemented for the emergency physicians and surgery/orthopedic residents simultaneously. However, the implementation of new rosters for the emergency physician will reduce the ED LOS even further if the emergency physicians' authority is also increased.

8.4.4. GP post appointment strategy – multi-level experimentation

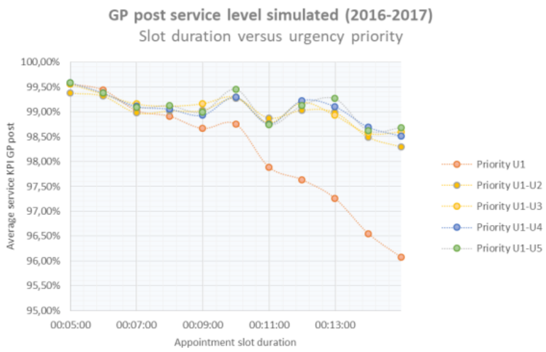
The GP post experiment results in Section 8.4.1 and Section 8.4.2 resulted that several trade-offs exist between the GP post's appointment strategy variables. The GP post LOS seems to increase if more patients are invited, while a decrease is expected if the slot durations are increased. The GP post's service level is changed in the opposite direction of the GP post LOS, indicating a clear trade-off between the two KPIs. A multi-level experiment for all three appointment strategy factors is conducted in order to find the best configuration, aiming for a LOS reduction while the service KPI remains at satisficing levels. Three factors are included in the multi-level experiment configuration:

1. Factor 1: Slot duration [minimum=5:00; interval=1:00; maximum=15:00];
2. Factor 2: Patient frequency [minimum=0.50; interval=0.25; maximum=1.00];
3. Factor 3: Urgency priority [minimum=U1 only; interval=+1 Urgency; maximum=U1-U5];

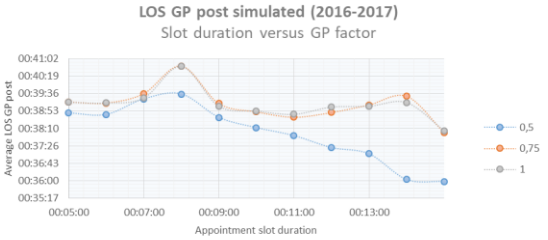
The trade-offs observed in Section 8.4.1 and Section 8.4.2 are also recognized results in Figure 62. The entrance LOS decreases if more either the patient frequency or the urgency priority increases, while the GP post LOS decreases at the same time. On the other hand, the GP post LOS decreases if the slot durations increase, while the entrance LOS decreases at the same time.



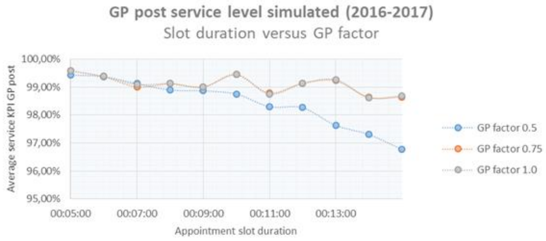
a) Slot duration versus urgency priority – LOS GP post



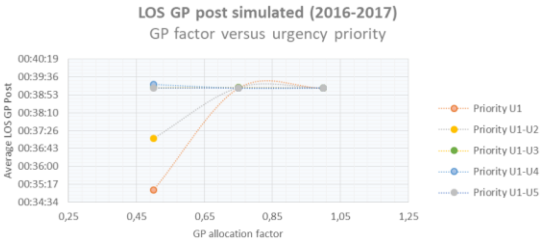
b) Slot duration versus urgency priority – GP post service



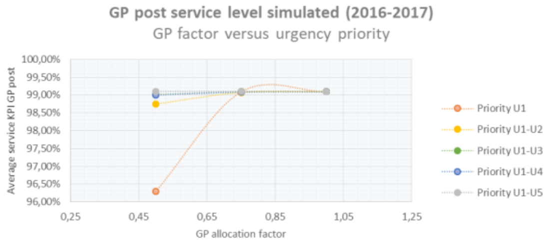
c) Slot duration versus patient frequency – LOS GP post



d) Slot duration versus patient frequency – GP post service



e) Patient frequency versus urgency priority – LOS GP post



f) Patient frequency versus urgency priority – GP post service

Figure 62: The entrance LOS (left) and GP post LOS (right) resulting from the alternative appointment strategies possible.

The visualizations in Figure 43 reveal that no quantitative optimal appointment strategy exists, the decision is strongly influenced by the decision maker's preferences. Therefore, several experiment configurations are ranked in order of their performances (Table 45 and Table 46).

LOS comparisons	Appointment strategy - Experimental settings				GP post KPIs			
	ExpID	Slot duration	Patient frequency	Urgency priority	LOS total	LOS entrance	LOS GP post	GP service KPI
Top 5 minimum LOS GP post	EXP151	00:15:00	0,50	U1 only	01:27:32	00:35:43	00:29:17	0,908
	EXP136	00:14:00	0,50	U1 only	01:26:27	00:33:19	00:30:10	0,923
	EXP121	00:13:00	0,50	U1 only	01:25:17	00:30:33	00:31:27	0,933
	EXP137	00:14:00	0,50	U1-U2	01:23:05	00:27:14	00:32:39	0,983
	EXP106	00:12:00	0,50	U1 only	01:23:44	00:27:56	00:32:53	0,946
	ExpID	Slot duration	Patient frequency	Urgency priority	LOS total	LOS entrance	LOS GP post	GP service KPI
Top 5 minimum LOS entrance	EXP03	00:05:00	0,50	U1-U3	01:19:51	00:19:27	00:37:37	0,995
	EXP04	00:05:00	0,50	U1-U4	01:20:09	00:19:32	00:39:03	0,996
	EXP05	00:05:00	0,50	U1-U5	01:20:18	00:19:37	00:39:15	0,996
	EXP09	00:05:00	0,75	U1-U4	01:20:18	00:19:37	00:39:15	0,996
	EXP10	00:05:00	0,75	U1-U5	01:20:18	00:19:37	00:39:15	0,996
	ExpID	Slot duration	Patient frequency	Urgency priority	LOS total	LOS entrance	LOS GP post	GP service KPI
Top 5 minimum LOS total	EXP03	00:05:00	0,50	U1-U3	01:19:51	00:19:27	00:37:37	0,995
	EXP24	00:06:00	0,75	U1-U4	01:19:53	00:19:47	00:39:13	0,994
	EXP25	00:06:00	0,75	U1-U5	01:19:53	00:19:47	00:39:13	0,994
	EXP26	00:06:00	1,00	U1 only	01:19:53	00:19:47	00:39:13	0,994
	EXP27	00:06:00	1,00	U1-U2	01:19:53	00:19:47	00:39:13	0,994

Table 45: Top five performing appointment strategy based on the GP post LOS, entrance LOS and the total LOS.

The LOS rankings in Table 45 result into the following recommendations:

1. The GP post LOS can be reduced by inviting less patients to the GP post for a physical consult. This can be done by increasing the average slot duration above 12:00 minutes. However, the GP post's service levels decrease to hard if these options are taken into consideration;
2. The Entrance LOS can be reduced by decreasing the average slot durations down to 5:00 minutes, while the number of patient arrivals allowed in each slot is increased at the same time. The number of non-urgent patients allowed in each slot can also be increased to obtain the same results;
3. The total LOS is mainly affected by the entrance LOS, the patient's waiting perspectives should be taken into account in order to determine which LOS value should be minimized.

Service KPI comparisons	Appointment strategy - Experimental settings				GP post KPIs			
	ExpID	Slot duration	Patient frequency	Urgency priority	LOS total	LOS entrance	LOS GP post	GP service KPI
Top 5 minimum GP service KPI	EXP151	00:15:00	0,50	U1 only	01:27:32	00:35:43	00:29:17	0,908
	EXP136	00:14:00	0,50	U1 only	01:26:27	00:33:19	00:30:10	0,923
	EXP121	00:13:00	0,50	U1 only	01:25:17	00:30:33	00:31:27	0,933
	EXP106	00:12:00	0,50	U1 only	01:23:44	00:27:56	00:32:53	0,946
	EXP91	00:11:00	0,50	U1 only	01:23:01	00:26:12	00:33:56	0,961
	ExpID	Slot duration	Patient frequency	Urgency priority	LOS total	LOS entrance	LOS GP post	GP service KPI
Top 5 minimum GP service KPI (>98%)	EXP61	00:09:00	0,50	U1 only	01:21:16	00:22:28	00:37:17	0,980
	EXP154	00:15:00	0,50	U1-U4	01:22:00	00:22:32	00:38:57	0,982
	EXP123	00:13:00	0,50	U1-U3	01:22:17	00:22:04	00:40:23	0,983
	EXP137	00:14:00	0,50	U1-U2	01:23:05	00:27:14	00:32:39	0,983
	EXP138	00:14:00	0,50	U1-U3	01:21:57	00:22:21	00:39:02	0,984
	ExpID	Slot duration	Patient frequency	Urgency priority	LOS total	LOS entrance	LOS GP post	GP service KPI
Top 5 maximum GP service KPI	EXP04	00:05:00	0,50	U1-U4	01:20:09	00:19:32	00:39:03	0,996
	EXP05	00:05:00	0,50	U1-U5	01:20:18	00:19:37	00:39:15	0,996
	EXP09	00:05:00	0,75	U1-U4	01:20:18	00:19:37	00:39:15	0,996
	EXP10	00:05:00	0,75	U1-U5	01:20:18	00:19:37	00:39:15	0,996
	EXP11	00:05:00	1,00	U1 only	01:20:18	00:19:37	00:39:15	0,996

Table 46: Top five performing appointment strategy based on the GP post service KPI.

The service KPI rankings in Table 46 result into the following recommendations:

1. Increasing the slot duration and reducing the number of patient arrivals per slot reduces the GP post LOS, but the service KPI drops significantly. Therefore, reducing the GP post LOS would not be recommended;
2. A minimum service level of 98% is obtained if the slot duration is 9:00 minutes or more, while more non-urgent patients are allowed in each time slot.
3. The service KPI is maximized by decreasing the slot durations and increase the number of patient arrivals per slot. However, the GP post LOS will increase significantly for these decisions.

8.4.5. Multi-level experiments

The 2^K experimental designs revealed which experiment factors will result into a significant improvement of the GP post LOS and/or ED LOS. The solution space is therefore reduced, enabling the execution of a multi-level experiment to find the optimal configurations for each KPI. Eight experimental factors are included into the multi-level experimental design:

1. Factor 1: Slot duration [minimum=10:00; interval=1:00; maximum=15:00];
2. Factor 2: Patient frequency [minimum=0.50; interval=0.25; maximum=0.75];
3. Factor 3: Urgency priority [minimum=U1 only; interval=+1 Urgency; maximum=U1-U2];
4. Factor 4: GP evening roster [Boolean];
5. Factor 5: GP visit buffer [minimum=1 only; interval=+1; maximum=3];
6. New roster ED doctor [Boolean];
7. New roster res 1 [Boolean];
8. New roster medical specialist [Boolean].

These experimental factors are selected with care. Alternative configurations of the GP post's appointment strategy and patient buffer size resulted to provide significant LOS improvements without increasing capacity. However, a trade-off was observed between the GP post LOS and the GP post service level. Therefore, it is interesting to find which configuration provides the lowest waiting time and highest service levels. The new staff rosters for both the GP post and the ED also resulted into significant LOS improvements, but are costly due to the staff acquisitions required. The new staff rosters are included into the multi-level design to evaluate which investment pays out the most in terms of reduced waiting times or increased service levels. The dedicated driver is excluded, because a fully authorized GP resulted to improve the LOS values more.

Not all experimental factors are included into the multi-level experimental design to reduce computational time. However, other experimental factors also resulted into significant KPI improvements. These experimental factors are simply held constant, because it is already known that the implementation would result into a significant improvement without positively or negatively influencing the results of other experimental factors. During the multi-level experimentations:

1. The GP post and the ED share their triage results in order to reduce the workload;
2. One GP is hired during the night every day to free staff capacity;
3. The GP post is fully responsible for the physical triage of self-referrals (if opened);
4. The ED performs the physical triage in the ED treatment rooms;
5. The emergency physicians may treat both labeled and unlabeled patients all the time;
6. Patients are directly admitted into the hospital if required.

The results of this multi-level experiment are given in Table 47. All experiments are replicated seven times, which provides 95% statistically significant results for the total LOS values (Table 39).

LOS comparisons	Appointment strategy - Experimental settings									GP post KPIs							
	Experiment ID	SlotDuration	SlotFrequency	UrgencyPriority	NewRosterEveningGP	GPVisitBuffer	NewRosterSA	NewRosterRES1	NewRosterSP	LOS total	LOS entrance	LOS GP post	LOS ED	Utilization GP post	Utilization ED	Service GP post	Service ED
Original settings	*-*	*00:10:00*	*0,5*	*U1 only*	*FALSE*	*1*	*FALSE*	*FALSE*	*FALSE*	*01:23:44*	*00:23:18*	*00:33:41*	*02:38:12*	*36%*	*29%*	*97%*	*92%*
Baseline settings	*-*	*00:10:00*	*0,5*	*U1 only*	*FALSE*	*1*	*FALSE*	*FALSE*	*FALSE*	*01:21:59*	*00:25:49*	*00:37:30*	*02:20:40*	*40%*	*31%*	*95%*	*94%*
Top 5 minimum LOS total	80	00:10:00	0,5	U1-U2	TRUE	1	TRUE	TRUE	TRUE	01:01:20	00:18:26	00:26:02	01:47:15	36%	27%	99%	93%
	176	00:10:00	0,75	U1-U2	TRUE	1	TRUE	TRUE	TRUE	01:01:27	00:18:13	00:26:08	01:47:50	36%	27%	99%	94%
	32	00:10:00	0,5	U1 only	TRUE	1	TRUE	TRUE	TRUE	01:01:33	00:18:38	00:25:44	01:47:44	36%	27%	99%	94%
	560	00:12:00	0,75	U1-U2	TRUE	1	TRUE	TRUE	TRUE	01:01:35	00:18:57	00:26:11	01:46:55	37%	27%	99%	94%
	128	00:10:00	0,75	U1 only	TRUE	1	TRUE	TRUE	TRUE	01:01:36	00:18:26	00:25:58	01:48:04	36%	27%	99%	94%
Top 5 minimum LOS entrance	121	00:10:00	0,75	U1 only	TRUE	1	FALSE	FALSE	FALSE	01:11:28	00:18:04	00:25:46	02:15:14	36%	30%	99%	94%
	176	00:10:00	0,75	U1-U2	TRUE	1	TRUE	TRUE	TRUE	01:01:27	00:18:13	00:26:08	01:47:50	36%	27%	99%	94%
	25	00:10:00	0,5	U1 only	TRUE	1	FALSE	FALSE	FALSE	01:11:41	00:18:14	00:25:41	02:15:33	36%	30%	99%	94%
	171	00:10:00	0,75	U1-U2	TRUE	1	FALSE	TRUE	FALSE	01:07:37	00:18:16	00:26:18	02:04:02	36%	29%	99%	93%
	173	00:10:00	0,75	U1-U2	TRUE	1	TRUE	FALSE	FALSE	01:05:04	00:18:17	00:26:20	01:57:07	37%	29%	99%	93%
Top 5 minimum LOS GP post	525	00:12:00	0,75	U1 only	TRUE	3	TRUE	FALSE	FALSE	01:09:01	00:25:32	00:24:02	01:56:15	35%	29%	95%	93%
	1001	00:15:00	0,5	U1 only	TRUE	3	FALSE	FALSE	FALSE	01:16:52	00:26:58	00:24:16	02:14:37	35%	30%	96%	93%
	1097	00:15:00	0,75	U1 only	TRUE	3	FALSE	FALSE	FALSE	01:16:31	00:26:29	00:24:16	02:14:31	35%	30%	96%	93%
	762	00:13:00	0,75	U1-U2	TRUE	3	FALSE	FALSE	TRUE	01:16:53	00:26:36	00:24:19	02:15:15	35%	30%	96%	94%
	1004	00:15:00	0,5	U1 only	TRUE	3	FALSE	TRUE	TRUE	01:11:37	00:26:54	00:24:19	02:00:22	35%	29%	96%	93%
Top 5 minimum LOS ED	464	00:12:00	0,5	U1-U2	TRUE	1	TRUE	TRUE	TRUE	01:01:37	00:18:55	00:26:35	01:46:34	37%	27%	99%	94%
	1032	00:15:00	0,5	U1-U2	FALSE	3	TRUE	TRUE	TRUE	01:13:25	00:32:49	00:33:12	01:46:43	37%	27%	93%	94%
	560	00:12:00	0,75	U1-U2	TRUE	1	TRUE	TRUE	TRUE	01:01:35	00:18:57	00:26:11	01:46:55	37%	27%	99%	94%
	72	00:10:00	0,5	U1-U2	FALSE	3	TRUE	TRUE	TRUE	01:11:34	00:30:04	00:32:47	01:47:06	37%	27%	94%	94%
	1024	00:15:00	0,5	U1-U2	FALSE	2	TRUE	TRUE	TRUE	01:13:11	00:31:40	00:34:30	01:47:11	38%	27%	94%	94%
Top 5 maximum GP post service	25	00:10:00	0,5	U1 only	TRUE	1	FALSE	FALSE	FALSE	01:11:41	00:18:14	00:25:41	02:15:33	36%	30%	99%	94%
	462	00:12:00	0,5	U1-U2	TRUE	1	TRUE	FALSE	TRUE	01:04:01	00:18:35	00:25:49	01:54:17	36%	29%	99%	93%
	314	00:11:00	0,75	U1 only	TRUE	1	FALSE	FALSE	TRUE	01:11:50	00:18:38	00:26:25	02:14:42	36%	30%	99%	94%
	218	00:11:00	0,5	U1 only	TRUE	1	FALSE	FALSE	TRUE	01:11:49	00:18:42	00:26:21	02:14:35	36%	30%	99%	93%
	704	00:13:00	0,75	U1 only	TRUE	1	TRUE	TRUE	TRUE	01:01:54	00:19:09	00:25:45	01:47:48	36%	27%	99%	93%
Top 5 maximum ED service	67	00:10:00	0,5	U1-U2	FALSE	3	FALSE	TRUE	FALSE	01:18:13	00:29:08	00:35:30	02:03:48	37%	29%	94%	94%
	254	00:11:00	0,5	U1-U2	FALSE	2	TRUE	FALSE	TRUE	01:12:46	00:26:39	00:35:14	01:54:17	38%	29%	96%	94%
	417	00:12:00	0,5	U1 only	TRUE	2	FALSE	FALSE	FALSE	01:14:11	00:22:14	00:25:36	02:14:55	35%	30%	98%	94%
	466	00:12:00	0,5	U1-U2	TRUE	2	FALSE	FALSE	TRUE	01:13:23	00:22:01	00:25:02	02:13:44	35%	30%	98%	94%
	521	00:12:00	0,75	U1 only	TRUE	3	FALSE	FALSE	FALSE	01:16:44	00:26:19	00:24:46	02:14:52	35%	30%	95%	94%

Table 47: Multi-level experiment results for all experimental factors significantly influencing the GP post LOS or ED LOS.

The yellow marked record in Table 47 indicates the original and baseline settings used for comparisons. The original settings represent the actual IEP organization of today, while the baseline settings include the experimental factors that are already optimized earlier during the 2^K factorial experiments like the direct hospital admission and the increased authority of the emergency physician. Several conclusions can be made from the multi-level experiment results in Table 47:

1. The logistic performances of the GP post and the ED are independent from each other, no statistical significant relationships can be found between the KPIs of both organizations;
2. Both the Entrance LOS and GP post LOS can be reduced by adding one GP to the evening shift from 5:00pm to 0:00am every day. The Entrance LOS will decrease by 8:55 minutes (-22%), and the GP post LOS is reduced by 5:04 minutes (-24%). No increase of the GP post's staff capacity is required for this alternative, because capacity is already freed by removing one GP from the night shift every day;
3. The entrance LOS can be reduced by a maximum of 5:14 minutes (-22%). The time slots should be as small as possible (10:00 minutes), while more patients are invited to each individual slot. No buffer should be made including patients waiting for a GP visit, the GP should leave the GP post by car as soon as possible. The GP post service level will be increased by 2%;
4. The GP post LOS can be reduced by a maximum of 9:39 minutes (-29%). Larger time slots are preferred in which more patients are invited, while a buffer of waiting patients should be created before a GP can leave the post for patient visits at home. The GP post service level is slightly reduced by 1%, resulting in a final service level of approximately 96%;
5. The ED LOS can be reduced by 52:38 minutes (-33%) by implementing new staff rosters for the emergency physicians and surgery/orthopedic residents. The medical specialist should also become immediate available if required to achieve the maximum ED LOS reductions. The implementation of new rosters for the emergency physicians results into the greatest ED LOS reduction, followed by the new staff rosters for the surgery/orthopedic residents. The increased availability of the medical specialist includes the smallest effect. The ED service level is not significantly affected by the new rosters implemented.

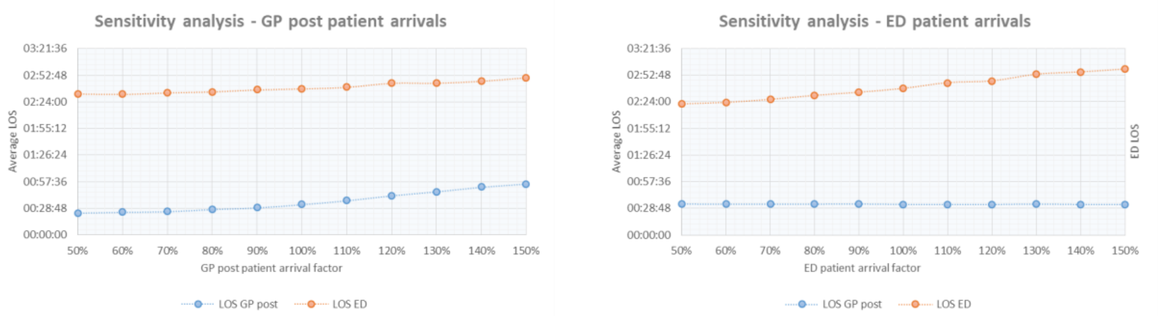
8.5. Sensitivity analysis

The solution validation in chapter 7 revealed that the GP post's and ED's input parameters change over the years. Especially the number of patient arrivals decreased since 2012, while more self-referrals are contacting the GP post since the integration in 2016. The activity durations also increase due to more complex treatments of the arriving patients. Therefore, a sensitivity analysis is conducted for these variables. Three alternative configurations are evaluated more closely:

1. Changing number of GP post patient arrivals (Figure 63a);
2. Changing number of ED patient arrivals (Figure 63b);
3. Changing average activity durations (Figure 64).

A percentage factor is used in order to increase the number of patient arrivals per hour or the average duration per activity. The factors range from 50% up to 150%. All other experimental settings are based on the results of experiment 80 in Section 8.4.5, which means that all recommended experimental factors are implemented in the simulation model.

The GP post LOS does not decrease significantly if the number of GP patient arrivals decreases. However, an increase of the GP post's patient arrivals results into significant incrases of the GP post LOS. For example, 50% more GP post patient arrivals will result into a 100% GP post LOS increase. The ED LOS is also affected by the GP post arrivals due to different number of GP post referrals. However, the effect is less in comparison with the GP post LOS.



a) GP post patient arrivals b) ED patient arrivals

Figure 63: Sensitivity analysis - number of patient arrivals

The ED LOS is also affected by the number of ED patient arrivals. Both a decrease and an increase of the patient arrivals results into a significant decrease or increase of the ED LOS respectively. The GP post LOS is not affected by the ED patient arrivals.

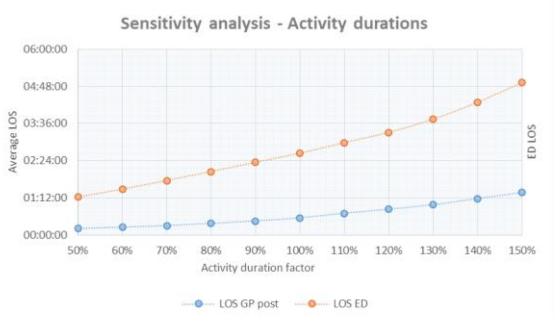


Figure 64: Sensitivity analysis - average activity durations.

The ED LOS is more affected by changing activity durations in comparison with the GP post LOS. This can be explained by the appointment strategy that the GP post can use, which provides some flexibility to coop with the increasing activity durations. The ED also faces higher utilization rates, which results into higher ED LOS values if the activities durations increase.

8.6. Experiment conclusions

In this chapter, new organizational configurations are designed and evaluated by using the new simulation model developed. The main aim is to optimize logistic performances of the IEP Enschede, including the GP post and the ED. Twelve alternative experimental factors are defined based on the problems identified during the problem identification phase and the solution validation.

The 2^K factorial design experiments revealed that some experimental factors can be implemented independently from all other experimental factors. The ED LOS can be reduced by direct admitting patients into the hospital (-21:23 minutes), increasing the emergency physicians' authority (-4:00 minutes) or performing the physical triage in the ED treatment rooms (-2:32 minutes). The ED LOS can also be improved by sharing the triage results between the GP post and the ED (-2:57 minutes), the GP post LOS is not improved however.

The GP post's performances can be improved by implementing an alternative appointment strategy. Tradeoffs exist between the GP post's LOS and service levels. The GP post LOS decreases if the slot durations are increased and less patients are invited, but this will also cause a reduction of the GP post service levels. The decision makers should first identify which service levels are acceptable for the GP post before the selection of a new appointment strategy.

The GP post LOS can be reduced by a maximum of 9:39 minutes (-29%). Larger time slots are preferred in which more patients are invited, while a buffer of waiting patients should be created before a GP can leave the post for patient visits at home. The GP post service level is slightly reduced by 1%, resulting in a final service level of approximately 96%. The service level can be increased by including smaller appointment slots and dispatching GPs for patient visits as soon as possible.

The ED LOS can be reduced by 52:38 minutes (-33%) by implementing new staff rosters for the emergency physicians and surgery/orthopedic residents. The medical specialist should also become immediate available if required to achieve the maximum ED LOS reductions. The implementation of new rosters for the emergency physicians results into the greatest ED LOS reduction, followed by the new staff rosters for the surgery/orthopedic residents. The increased availability of the medical specialist includes the smallest effect. The ED service level is not significantly affected by the new rosters implemented.

Special attention is required for the number of patients referred to the ED from the GP post, both the GP post LOS and ED LOS are strongly affected by these type of variable changes.

Chapter 9 – Conclusions & discussion

9.1. The problem description

9.1.1. Initial problem description

During the last two decennia, the organization of the (out-of-hours) emergency care has radically been changed within the Netherlands. Most patients could decide for themselves to visit the GP, go the hospital's ED directly or call the national emergency number. This type of organization resulted into an inefficient way of providing emergency care, which explains the motivation to generate, evaluate and implement alternative emergency care layouts. One of these alternatives is to integrate the GP post and the ED in one organization, which would force self-referrals to contact the GP post first. The integration also enables to improve the resource allocations and to reduce the waiting times for both the GP post and the ED.

9.1.2. The central action problem

The managers from HDT-Oost, MST and Acute Zorg Euregio do not know exactly how to quantify the improvements realized by the integration of the hospital's ED and GP post in Enschede. A clear overview of the benefits and disadvantages of the IEP implementation would allow the stakeholders to make fully informed decisions regarding the organization's layout, processes and resources. Better understanding could therefore result into an effective and efficient delivery of emergency care in Enschede. Therefore, the action problem can be defined as following:

Action problem: Incomplete insights into the actual performances of integrating the GP post and hospital's ED in Enschede obstruct HDT, MST and Acute Zorg Euregio to organize the out-of-hours emergency care both effectively and efficiently.

9.1.3. Research objectives & research question

The IEP Enschede is operational for 2 years. New patient records and process data are now available including the actual IEP performances, which results into new research opportunities. First, it is possible to quantify and visualize the actual performances of the ED and GP integration. Second, these performances can be compared with the initial recommendations made by Koster (2014) to validate the implemented solution of the generic simulation model developed by Mes & Bruens (2012). Finally, new recommendations can be made based on the additional insights gained, aiming to optimize boht patient satisfaction levels and organizational efficiencies within the IEP Enschede. Therefore, the main research question driving this study can be defined as following:

Central research question: How can the out-of-hours care within the IEP Enschede be improved by validating the solutions obtained from a general discrete-event simulation framework?

9.2. Conclusions

Several sub questions are developed to answer the central research question. Each chapter is dedicated to provide an answer for one or more sub-questions. In this section, the conclusions made in each chapter are summarized. Answering these questions will help to solve the action problem described in both Section 1.4.3 and 9.1.2.

Research question 1: Which improvements are expected from integrating the GP post and hospital's ED in Enschede?

The main improvement expected by the IEP implementation would be the removal of self-referrals at the ED during the out-of-hours emergency care. Alternative improvements are also expected like reductions of patient waiting times, increased patient satisfaction levels and efficient resource allocations due to stronger collaborations between stakeholders. Scientific literature only describes the theoretical results expected from the IEP implementation, while some articles include actual qualitative results regarding employee satisfaction levels only. However, no study is found so far that evaluates the actual quantitative effects of integrating the GP post and the ED.

Research question 2: Which analytical framework could be applied in order to validate and simulate processes of the IEP Enschede?

No standardized analytical framework exists in scientific literature to execute the solution validation in comparison with the other validation techniques. Most of the validation frameworks available do indicate the importance of solution validation. This final activity is required to compare the expected and actual performances of the recommendations made, allowing the investigators to adapt the implementations made over time. However, all these frameworks assume that the configurations actually implemented forms the only variable that has changed since the beginning of the simulation study. The input variables and process descriptions are assumed to be unchanged, which seems unlikely because more system characteristics can change over time. Therefore, the proposed solution validation framework in Figure 9 does not include the simple comparison between one recommended configuration and one real world description only, but a lot of alternative comparisons between the data sets, model descriptions and configurations simulated are included.

Research question 3: How is the out-of-hours emergency care organized within the separated GP post and ED (2014-2015) and the IEP Enschede (2016-2017)?

The emergency care organization in Enschede in Chapter 3 is described for two situations: 1) the separated provision of emergency care before integration in 2014-2015 and 2) the emergency care after integration of the GP post and ED in 2016-1017. The description of the actual emergency care organization is expended in Chapter 5 where the input variables are evaluated in more detail. Three main process classifications identified for both the separated and the integrated organization:

1. **Patient admittance**: this main process forms the entry point for either the GP post or ED and consists of both telephonic and physical triage of new patients;
2. **GP post activities**: the out-of-hours care provided by the GP post staff, consisting of 1) providing advice; 2) visiting the patients at home and 3) giving consultations.
3. **ED activities**: the out-of-hours care provided by the hospital's ED, consisting of 1) anamnesis; 2) diagnostics and 3) the actual treatment (Koster, 2014).

Alternative patient care pathways are identified for the GP post arrivals, GP post physical consult departures, ED arrivals and ED departures. The care pathway allocated depends on the NTS urgency classification assigned to the patient. If the patients requires physical treatment by either the GP post or the ED, several resources have to be allocated before starting the next activity (room, staff and diagnostic resources). ED patients are also allocated to a treatment group for proper staff allocations, the emergency physicians are allocated if the ED patient arrives unannounced or by ambulance.

Research question 4: How do the processes, patient flows and resource allocations within the IEP Enschede differ between the expectations from 2014 and the actual organization today?

The first and most important change in this research is represented by the decision to integrate the GP post and the ED or not. Secondly, the changes in the IEP's input parameters and organizational choices changed a lot over the years and should be investigated in more detail. The modifications made in comparison with the initial model of Koster (2014) are described in Chapter 4, while the model's input variables are elaborated in Chapter 5. A brief description of the main modifications is given below:

1. The patient arrival patterns remained unchanged for both the GP post and the ED, but the arrival rates decreased each year. The GP post faces more self-referrals, while the ED only helps self-referrals once the GP post is closed;
2. The GP post and ED make use of the same triage system, but the urgency classifications are still made independently from each other. The triage activity is performed for all ED patients, ED patients undergo the triage in a treatment room;
3. If the GP post is opened, the GP post staff is responsible for the triage of all self-referrals arriving at the IEP. ED triage nurses support the triage of self-referrals during the night.
4. A new appointment strategy is in use for the GP post's physical consults. New patients are scheduled in time slots of 10:00 minutes each;
5. The ED treatment group allocation is based on staff allocations made in real-life instead of the patient's entrance complaints. Staff may be called to the ED from an external hospital department if required;
6. A nested room allocation strategy based on the patient's urgency classification is applied instead of dedicated rooms only.

Research question 5: Which modifications are required in order to make Koster's simulation model up-to-date to the new conceptual model?

The simulation model's reusability is improved by inserting as many input variables into table files. New decision logic was required to simulate the GP visits and physical consults within the GP post itself properly. The GP post's appointment strategy, the staff allocations for physical GP consults and the availability of the GP post car are updated. New decision logic was also required for the simulation of ED processes, including the physical triage of self-referrals arriving at night, changing the ED rooms' availability, allowing the ED's emergency physicians to transfer responsibility of a patient's treatment and the possibility to invite residents to the ED from an external hospital department if required. ED treatment group allocations are also modified. The new simulation model is used to simulate the IEP 24/7. The number and type of patient arrivals, care pathway allocations and urgency classifications are determined properly by the simulation model, the processing times are also generated according to the probability function hypothesized. The model correctly represents the separated (2014-2015) and integrated (2016-2017) emergency care organization in Enschede. Therefore, the results are validated twice, which will support the simulation model's reliability.

Research question 6: How do the performances differ for both the separated and integrated emergency care organization in Enschede from 2012 up to 2017?

Both the actual GP post LOS and the ED LOS increased over the years by +17.8% and +15.1% respectively. The application of the customized solution validation framework makes it possible to find plausible causes for these LOS increases. The three components of the solution validation framework are separately discussed:

1. **Data modifications:** the number of GP post and ED arrivals decreased over the years while the average durations increased for both the GP post and the ED. Staff rosters also changed significantly, resulting in different utilization rates and waiting times. The ED LOS is mainly affected by the type of patient arrivals due to the changing resource requirements. The number of diagnostic test requests decreased, but the average durations increased.
2. **Model modifications:** the implementation of today's input variables into the simulation model made by Koster (2014) did not result into a proper representation of the system's actual behavior. Therefore, the conceptual model should be updated to gain reliable simulation results. In the new simulation model, the GP post's appointment strategy is modified, new staff allocations are available and the GP visits are better organized. A nested room prioritization is used for all ED treatment rooms, unlabeled patients undergo the triage at the treatment room and residents can be called to the ED from an external hospital department.
3. **Alternative configurations:** the LOS increases are partly explained by the decision to integrate the GP post and the ED. The number of self-referrals contacting the GP post has increased since the integration. However, the high frequency of calling patients allowed the GP post to schedule the arriving patients smartly, resulting into a slight increase of the patients' LOS while the GP utilization rate is relatively high. The ED does not see any out-of-hours self-referrals anymore, but the number of GP post referrals arriving at the ED increased. The new type of ED arrivals require treatment from the staff members that were already highly utilized. Therefore, the ED LOS still increases due to longer waiting times.

The solution validation enables the stakeholders to understand how their operations actually work. The necessity to validate the simulation results makes it possible to see which new configurations have been implemented over time. Comparing the expected and actual IEP performances enables the decision makers to alter their future plans. The solution validation also revealed both past and current bottlenecks within the processes, allowing to construct new experiments. As a result, more insights are gained into the effects of the IEP implementation and the possibility arises to investigate the improvements of new configurations.

Research question 7: Which organizational configurations will optimize the out-of-hours care within the integrated emergency post of Enschede?

The 2^K factorial design experiments revealed that some experimental factors can be implemented independently from all other experimental factors. The ED LOS can be reduced by direct admitting patients into the hospital (-21:23 minutes), increasing the emergency physicians' authority (-4:00 minutes) or performing the physical triage in the ED treatment rooms (-2:32 minutes). The ED LOS can also be improved by sharing the triage results between the GP post and the ED (-2:57 minutes), the GP post LOS is not improved however.

The GP post LOS can be reduced from 33:41 minutes originally to 24:02 minutes, which includes a maximum reduction of 9:39 minutes (-29%). Larger time slots are preferred in which more patients are invited, while a buffer of waiting patients should be created before a GP can leave the post for patient visits at home. The GP post service level is slightly reduced by 1%, resulting in a final service level of approximately 96%. The service level can be increased by including smaller appointment slots and dispatching GPs for patient visits as soon as possible. It is recommended to create new rosters for the GP, including an additional GP for all evening shifts. The roster modification can be made without expending the GP post's staff capacity, because one GP can be removed from each night shift without negative consequences for the service rate.

The ED LOS can be reduced from two hours and 38:12 minutes to only one hour and 46:34 minutes, which includes a maximum reduction of 52:38 minutes (-33%) by implementing new staff rosters for the emergency physicians and surgery/orthopedic residents. The medical specialist should also become immediate available if required to achieve the maximum ED LOS reductions. The implementation of new rosters for the emergency physicians results into the greatest ED LOS reduction, while the increased availability of medical specialist includes the smallest effect. The ED service level is not significantly affected by the new rosters implemented.

Not all experiments resulted into a significant KPI improvement. The LOS values are not improved if the GP post and the ED share each other's' rooms, the room capacity is not the bottleneck. The decision to transfer responsibility of the physical triage either the GP post or the ED did not provide any significant KPI improvement. The dedicated driver also resulted into significant improvements, but the allocation of an additional GP provided better results due to larger flexibility. No staff capacity increases are required for the residents of the specialist types "Pulmonary Medicine", "Internal medicine", "Gastrointestinal & Liver" and "Neurology". Special attention is required for the number of patients referred to the ED from the GP post, both the GP post LOS and ED LOS are strongly affected by these type of variable changes.

9.3. Recommendations

The main problem discussed in Chapter 1 is the lack of insights into the results of the IEP implementation in Enschede since the 11th of January 2016. This problem is solved by customizing the solution validation framework developed in this research. The comparison of all data modifications, model adjustments and alternative configurations make it possible to identify the factors that influenced the actual IEP performances the most. It is recommended to keep track of the modifications made in the IEP's conceptual model, a well-documented description of the IEP organization makes it easier to find plausible causes for the performances observed.

The solution validation also revealed both past and current bottlenecks within the processes, allowing to construct new experiments. The following recommendations are made to reduce the GP post LOS and ED LOS by 9:39 minutes (-29%) and 52:38 minutes (-33%) respectively.

GP post recommendations:

1. Increase the appointment slot duration to 15:00 minutes and invite two patients for each slot.
2. Only prioritize U1 patients for making an appointment, these patients negatively influence the GP post's service level the most.
3. Remove one GP from the night shift every day to free staff capacity and add one GP to the evening shift from 5:00pm to 0:00am every day;
4. Do not dispatch the GP for patient visits at home immediately, wait until a buffer of 3 waiting patients is created. This will reduce the IEP's waiting times and avoid unnecessary driving;

ED recommendations:

1. Increase the staff capacity up to two members physically present at the ED for either the emergency physician or the surgery/orthopedic residents, especially from 8:00am to 6:00pm;
2. Increase the emergency physicians' authority, allowing them to treat both labeled and unlabeled patients at any time;
3. Close the dedicated triage room and perform the physical triage in the ED treatment rooms, this will make sure that an ED nurse can start the triage activity sooner. Enough rooms are available to avoid stacking of patients in the ED waiting room;

4. Make strict agreements with the acute admission department to speed up the patient's admission into the hospital to free room capacity;
5. Make strict agreements with each specialist department that one medical specialist can be contacted or invited to the ED at any time, without any delay;
6. Make use of the GP post's triage results if available to avoid rework;
7. Redesign the residents' staff rosters based on the actual number of patients requesting emergency care per hour. For example, the total staff capacity for internal medicine residents can be reduced without consequences for the ED LOS or service levels;

9.4. Research limitations & further research

9.4.1. Research limitations & further research - IEP Enschede

The GP post LOS can be reduced by the implementation of a new appointment strategy. This research did only take static appointment strategies into account, because the decision rules of these strategies could be reused by the GP assistants easily. However, it is interesting to investigate if the GP post's KPIs can be improved by implementing more complex and dynamic appointment strategies like stochastic job shop scheduling algorithms.

The ED LOS is strongly affected by the number of serial activities required. For example, if the patient is treated by a surgical resident, requires one diagnostic test only, no support is asked from the ED nurse or medical specialist and the patient leaves home directly after its treatment, a minimal duration of 90 minutes is required on average. Therefore, it may be interesting to redesign the ED patient care pathways itself. The triage activity and the anamnesis may be integrated into one new activity for example, or the diagnostic tests are already requested before the patient's treatment group is known.

Some of the recommendations do include multiple stakeholders. These type of recommendations are promising, but require stronger collaboration between different stakeholders. For example, the ED LOS can also be reduced if patients do not have to wait for hospital admission. However, the waiting time for hospital admission is mainly caused by the high workload at the successive department. A feasibility study should be conducted to investigate if collaboration is possible.

The simulation model can be validated in more detail if the ED patient records include more data registrations regarding the patients' events. Most of the GP post patient records include automatic registration of system modifications, which results in reliable source for the simulation model's data input. However, the ED patient records do not include all types of state modifications, only the patient's arrival, departure, staff- and urgency classification are stored correctly. If the ED's data registration is improved, the simulation model's input can be made more reliable. The ED's data registration is very useful for the trauma registration required by law, but an improved data registration also allows the ED stakeholders to analyze their own processes in more detail.

Some of the simulation model's simplifications should be investigated in more detail. For example, staff members are assumed to be immediately available once they become idle. Rework is also not taken into account, assuming that all patients complete its patient care pathway sequentially. This is not the case in real-life. It would be interesting to investigate these type of model modifications in more detail, which will provide useful information for the staff rosters for example. New experiments can be designed to evaluate the IEP performances once rework is actively prevented.

A very weak but significant seasonal effect is observed during the week factor analysis for both the GP post and the ED. The impact of this week factor can be analyzed in more detail in order to find plausible explanations for the increased workload experienced by staff members;

9.4.2. Research limitations & further research – scientific contribution.

This research revealed a clear overview of the actual IEP performances. However, it is recommended to apply the activity of solution validation to other IEP locations outside of Enschede as well. The IEP Enschede forms an integrated entity in the patient's perception, but the staff members still experience a strictly separated organization of the GP post and the ED. For example, the IEP Almelo does not only perform the triage activity together, but here the GP post and the ED can also some of their rooms. True conclusions about the general IEP results can be made if alternative IEP configurations are also validated in more detail.

The solution validation provides useful information to improve the simulation model's accuracy. The bottlenecks observed during the comparison of actual and simulated results can be used to design new experiments that actually improve the system's performances. Therefore, the solution validation provides a feedback loop into the simulation study, which allows the investigator to improve the initial design even further. The activity of solution validation should form a self-evident step within a simulation study. Most simulation frameworks do include some guidelines, but no clear link is made with the other simulation steps. Further research should be made to improve the simulation validation frameworks to invite modelers to think critically about how to increase the probability of a successful implementation of the configuration(s) recommended.

The application of sensitivity analyzes is widely used in simulation studies, but new sensitivity analysis techniques should be developed to make room for the activity of solution validation. The sensitivity analysis should not be used only to determine when the output variables will change significantly due to modification of a 'small' set of input variables. More attention should be assigned to finding those input variables that would disrupt the system the most. These critical variables should be monitored to initiate the solution validation activity.

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MASTER THESIS

APPPENDICES

CORRESPONDING TO:

INTEGRATED EMERGENCY POST IN ENSCHEDE BY THE DEVELOPMENT OF A SOLUTION VALIDATION FRAMEWORK

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27th of November 2018

UNIVERSITY OF TWENTE.

Preface appendices

Please note that not all appendices are included in the public thesis due to confidential information.

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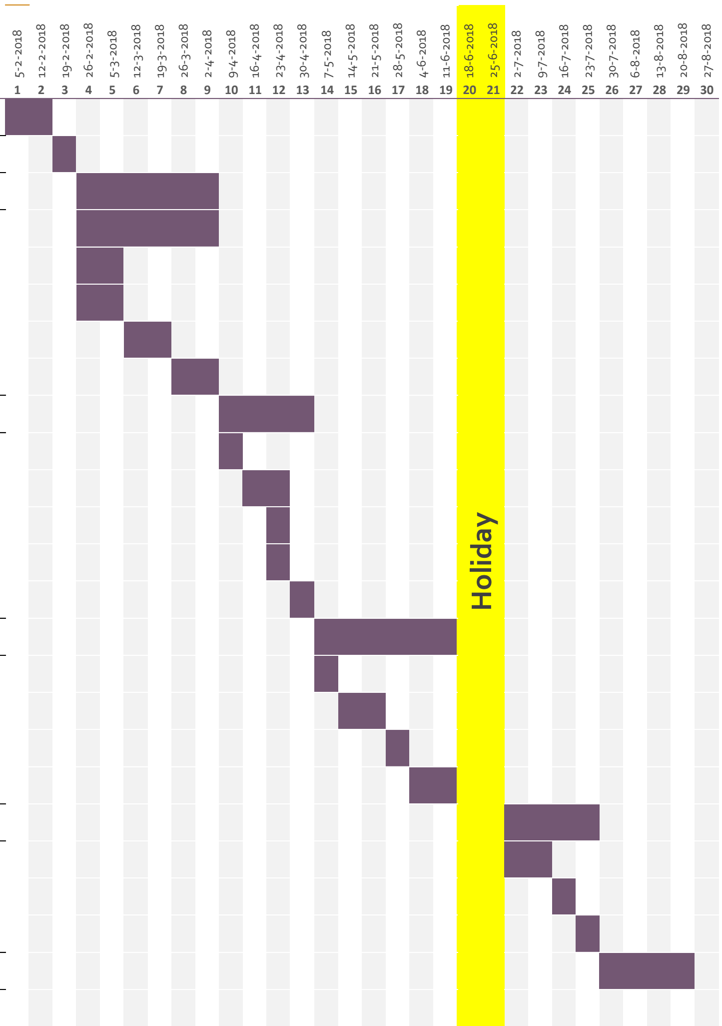


Appendix C – NTS urgency classifications

Both the GP post and the ED make use of a triage decision support system in order to determine the patient's urgency level en follow-up action required. Nowadays, the GP post and the ED make use of the same standardized system, the "Nederlandse Triage Standaard" (NTS). Triage nurses use the NTS in order to categorize all arriving patients into six different urgency levels, resulting into different maximum waiting times allowed for each level. An overview of the urgency levels is given within *Table 3*, including the maximum waiting times for each urgency level.

Code	Color	Title	GP post max waiting time	ED max waiting time
U0	Red	Resuscitation	0 minutes	0 minutes
U1	Orange	Life threatening	15 minutes	10 minutes
U2	Yellow	Emergency	60 minutes	60 minutes
U3	Green	Urgent	180 minutes	120 minutes
U4	Blue	Not urgent	∞ minutes	240 minutes
U5	White	Advice	∞ minutes	Not applicable

Table 48: Different urgency levels used within the "Nederlandse Triage Standaard", including the maximum waiting times.

Most of the GP post's patients are classified as U3 (green) patients (Table 49 and Figure 65). These type of patients require immediate care the day they contacted the GP post, they cannot wait to visit their own GP the next day. The second largest group of patients is classified as U5 (white), also U4 (blue) patients are contacting the GP post frequently. These type of patients didn't require any immediate care at all, indicating unnecessary utilization of the emergency care resources. The total number of patient requesting the GP post for out-of-hours emergency care increases every year. However, the number of non-urgent patient (U4 and U5) decreases both absolutely and relatively.

Arrival year	U0	U1	U2	U3	U4	U5	Missing	Total
2014	3	1042	6033	13252	6125	11109	9027	46591
2015	10	1056	6230	16678	4643	10539	9475	48631
2016	5	1288	7222	16774	4633	10581	10069	50572
2017	5	1222	7093	17081	4778	10228	10760	51167
Non-integrated post (<2016)	13	2098	12263	29930	10768	21648	18502	95222
Integrated post (>=2016)	10	2510	14315	33855	9411	20809	20829	101739
Total	**23**	**4608**	**26578**	**63785**	**20179**	**42457**	**39331**	**196961**

Table 49: A quantitative overview of the patients' urgency colours allocated by the GP post. The urgency allocations before and after the integration of the GP post and ED are compared.

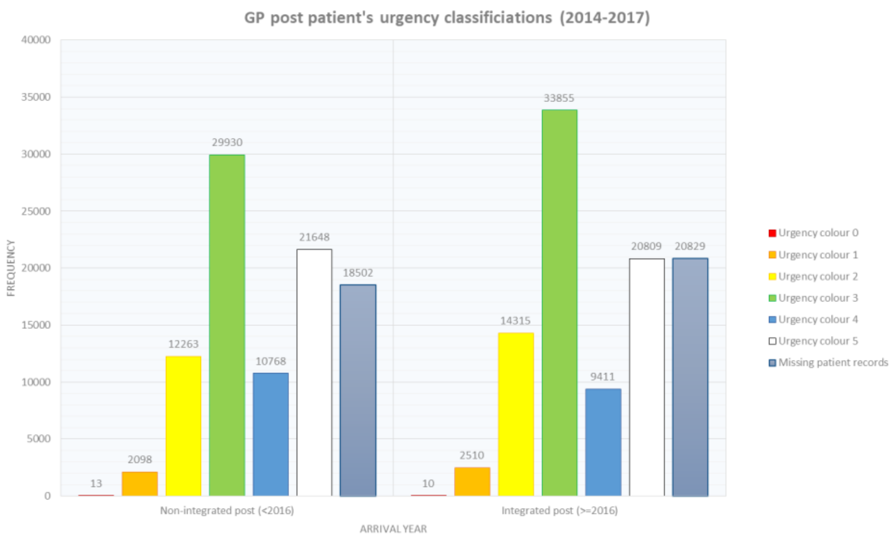


Figure 65: A visualized distribution of the patients' urgency colours allocated by the GP post. The urgency allocations before and after the integration of the GP post and ED are compared.

The total number of patients visiting the ED decreases every year (Table 50 and Figure 66). This pattern should be expected, because of the reduced number of ED self-referrals due to the integration with the GP post. Most of the ED's patients are classified as U2 (yellow) patients. These type of patients represent the emergency cases and require immediate care within one hour. The second largest group of patients is classified as U3 (green), they also require immediate care but with less urgency.

Arrival year	0	1	2	3	4	5	Missing	Total
2014	3	435	3871	14085	10204	61	1	28660
2015	5	469	4317	13808	7846	98	5	26548
2016	956	294	3461	10496	8776	1147	669	25799
2017	1293	317	3326	11064	9128	409	25	25562
Non-integrated post (<2016)	8	904	8188	27893	18050	159	6	55208
Integrated post (>=2016)	2249	611	6787	21560	17904	1556	694	51361
Total	2257	1515	14975	49453	35954	1715	700	106569

Table 50: A quantitative overview of the ED patients' urgency colours allocated by ED. The urgency allocations before and after the integration of the GP post and ED are compared.

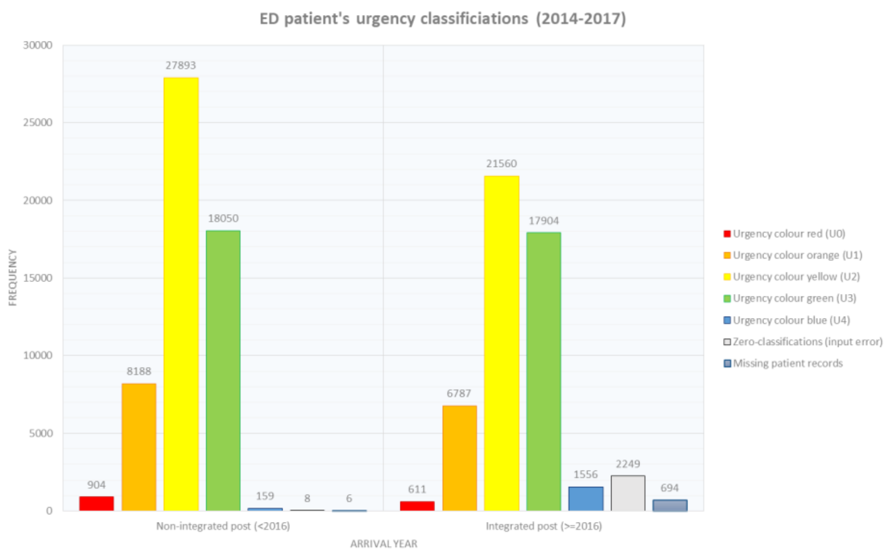


Figure 66: A visualized distribution of the patients' urgency colours allocated by the ED. The urgency allocations before and after the integration of the GP post and ED are compared. The U0 urgency classifications are not recognized within the ED triage system, these urgency classifications represent a missing input value only.

By examining the urgency distributions in Figure 65 and Figure 66, it can be concluded that the urgent and non-urgent patients are correctly allocated to the ED and GP post respectively. Most urgent patient (U0, U1 and U2) are treated by the ED, while less urgent patients (U3, U4 and U5) visit the GP post instead. However, some remarkable comparisons could be made. First of all, the number of non-urgent patients visiting the ED seems to be too small in the years 2014 and 2015, especially if you take into account that self-referrals could visit the ED without contacting the GP first. Secondly, the total number of urgent patients contacting the GP post increases over the years, while the number of ED patients decreases for all urgency classifications available. Finally, a relative large part of patient records do not include any classification at all.

Appendix G – The process constraints

The emergency care activities in Enschede are classified into three main clusters which are assumed to be independent from each other: 1) the patient admittance process; 2) the GP post activities and 3) the ED's activities. The process constraints are also classified into these three clusters. *Table 52*, *Table 53* and *Table 54* provide an overview of all constraints made for these process classifications, while *Table 51* includes some general assumptions that apply to both organizations.

ID	Overall constraints
1	All idle staff members at the GP post or ED are immediately available for new allocations.
2	The absence rate is equal to 0% for all staff members within the GP pots and ED, all staff members arrive and departure as given within the staff rosters.
3	A diagnostic employee is always available once requested the GP post or ED.
4	The GP post's and ED's patient arrivals are assumed by Poison distribution. The arrival rates depend on three factors only: a) an hour factor; b) a day factor and c) a week factor. These factors are based on historical data.
5	The processes in the GP post and the ED are independent of each other.
6	The waiting room capacities are unlimited for both the GP post and the ED.
7	Children patients arrivals are not taken into account, these patients are treated like all other adults.

Table 51: The assumptions made regarding the ED's activities.

ID	Patient admittance constraints
8	The durations of the patient's physical admittance process are assumed to be equal for both the GP post and ED;
9	The patient's urgency classification is based on the triage nurse's opinion, the urgency classification proposed by the NTS decision support system are not taken into consideration;
10	The patient's care path is based on the triage nurse's opinion, the actions recommended by the NTS decision support system are not taken into account.
11	All GP assistants are available for telephonic triage only, but one of these GP assistants is also reserved for the physical triage of self-referrals.
12	There are no patient arrivals at the GP post with an U0 urgency classification (resuscitation), because of the very limited frequency. These type of patients will probably contact the national emergency number first.
13	There are no patient arrivals at the ED with an U5 urgency classification, this classification is never used by the ED itself.
14	The coordinating GP assistant is also available for the telephonic triage activity.
15	The physical triage of all self-referrals within the ED is performed by a dedicated triage nurse.
16	All ED nurses are qualified to conduct the triage activities for the unlabeled external and unlabeled GP post referrals within the treatment room itself.
17	All ED patients have to undergo the triage activity within the ED, even if the patient's urgency classification is already determined by the GP post. This statement is valid for the separated and integrated out-of-hours emergency care organization.
18	The GP post is accountable for the out-of-hours triage activities since the IEP implementation, but the ED triage nurse is responsible for the execution at night between 11:00pm and 8:00am.
19	The patient's logistic care path is predefined during the patient's admittance procedure, the selection is based on the allocation's frequencies only. The frequencies are obtained from the historical patient records.

Table 52: The assumptions made regarding the patient admittance processes in front of the arrival at the GP post or the ED.

ID	GP post constraints
20	Only one action is allocated for all the GP post's patients, rework requirements and online modifications of the patients' care paths are not taken into account. Please notice that all patients also have to undergo the telephonic or physical triage activity, depending on their arrival type.
21	The provision of advice by a GP assistant is considered to be part of the triage activity. Therefore, the processing time required for the advice itself is assumed to be equal to zero.
22	Calling patients that require a physical consult are scheduled in time slots of 10 minutes. Each time slot may require one patient, but one emergency patient (U1 or U2) may be added to each time slot. Note that these time slots do not represent the appointment for the physical consult, it only represents the patient's arrival. The patients always arrive on time
23	Calling patients may arrive before or after their appointment time. The length of stay is calculated from the moment the patient arrives at the GP post physically, but the patient may not be treated before its appointment time has passed. Only high urgent patients (U1) are invited for the physical consult as soon as possible, even if the patient arrives earlier.
24	The patients' consults are prioritized by comparing the maximum waiting time allowed for the patients' urgency classifications and the patients' actual waiting time.
25	Only GPs and NPs can conduct a physical consult during the separated out-of-hours emergency organization. Nowadays it is possible to allocate three alternative staff types in order to perform the physical consult: a) a GP. b) a GP assistant or c) a NP. The processing times differ for all staff types, but the departure ratios remain the same.
26	Only one staff member is allocated to the patient's care, the transfer of responsibility or the support of another staff member within the GP post is not taken into account.
27	There is no travel time calculated for both staff members and patients in between two successive activities, the patient's traveling time from its home to the GP post and the GP visits form the only exception of this assumption.
28	One GP should remain present at the GP post during the night on business days, weekends and national holidays.
29	Two GPs should remain present at the GP post between 8:00am and 5:00pm during weekends and holidays.
30	The directing GP is only available in order to support the GP assistants with the triage decisions between 7:00pm and 10:00pm every day, the directing GP is not available for other staff allocations.
31	The request of a diagnostic test is randomly selected, based on the historical frequencies obtained from the GP post's and ED's patient records. The diagnostic test is executed right after finishing the physical consult, the patient does not have to return to the GP in order to evaluate the results.
32	Six GP post rooms are available for the physical GP post consults, which consist of four consultation rooms and two treatment rooms. These rooms are assumed to be equal to each other.

Table 53: The assumptions made regarding the GP post's activities.

ID	ED constraints
33	All ED patients undergo the same main activities: a) physical triage; b) the anamnesis; c) the request, execution and review of diagnostic tests and d) the treatment itself. Patients cannot skip one of these activities.
34	The ED's main activities are executed successively for all patients, rework requirements and online modifications of the patients' care paths are not taken into account.
35	The time that anamnesis takes does not depend on the staff member that performs this process (Koster, 2014).
36	The time required for room and staff allocations is assumed to be approximately equal to zero.
37	Some treatment rooms are dedicated for special types of patients, like children rooms or throat, nose and ear patients, but it is assumed that all type of patients can be treated in all type of treatment rooms available at the ED. Only the plaster room and diagnostic test equipment are differentiated.
38	Diagnostic room number 20 is not used within the simulation, because it should be reserved for actual barrier treatments.
39	The two trauma rooms are dedicated to red (U0) and orange (U1) patients, only the X-ray equipment may be used for other urgency classifications. The acute rooms are dedicated for red (U0), orange (U1) and yellow (U2) patients.
40	The allocation of patients to the available treatment rooms is prioritized by comparing the maximum waiting time allowed for the patients' urgency classifications and the patients' actual waiting time.
41	The allocation of staff and additional resources to the anamnesis, diagnostic testing and treatment of patients are also prioritized by comparing the maximum waiting time allowed for the patients' urgency classifications and the patients' actual waiting time.
42	Only one type of specialist is allocated to the patient's care, the transfer of responsibility or the support of another specialist is not taken into account. The ED doctors form the only expectation for this assumption. The ED doctor is responsible for the patient's anamnesis and diagnostic testing, but the treatment may be transferred to another medical specialist, which is based on the historical frequencies obtained from ED's patient records. The patient may be treated by multiple persons of the same specialist type however.
43	The ED nurses may support the ED doctors, residents and medical specialist at all types of activities. A fixed percentage applies to all types of activities in order to allocate an additional ED nurse to the staff allocations.
44	The activities' durations differ for each type of staff member allocated. The durations are assumed to be fixed due to the limited availability of intermediate time registrations within the ED's patient records. Only the durations of the diagnostic tests offered by the radiology department are based on historical data.
45	The probability that certain diagnostic tests are requested depends on the type of specialist allocated to the patient's treatment.
46	A diagnostic employee is immediately send to the ED once requested, which requires some travel time.
47	The diagnostic test results become available at the ED immediately once the test itself is completed.
48	There is no travel time calculated for both staff members and patients in between two successive activities, only staff members who are requested to the ED from an external department require some additional travel time.

Table 54: The assumptions made regarding the ED's activities.

Appendix H – Conceptual model's level of detail

Component	Sub-component	Included GP post?	Included ED?	Comments
Patient	Arrival type	Included	Included	All arrival types are included, because the triage activity and patient's characteristics differ for external-, GP post- and self-referrals.
	Arrival rate	Included	Included	Assumed to follow a Poisson distribution, the arrival rate depends on the hour, day and week. Based on historical data from the patient records.
	Entrance complaints	Excluded	Excluded	The urgency classification and action selected are based on the entrance complaints given by the patient. The results are used only in order to reduce complexity.
	Urgency classification	Included	Included	Required for prioritizing the resource allocations, appointment scheduling and patient prioritization.
	Action selected	Included	Excluded	The number of activities proposed by the GP post is limited to four alternatives: 1) advice given by the GP assistant. 2) a physical consult at the GP post. 3) a GP visit at the patient's home or 4) a telephonic consult conducted by a GP. All other activities like NP visits are not taken into consideration due to the limited frequencies of these remaining GP post activities. The number of activities proposed by the ED is limited to four alternatives: 1) physical triage; 2) anamnesis; 3) Diagnostic testing and 4) treatment. All ED patient's walk through these four steps.
	Specialist allocated	Excluded	Included	Only one specialist is allocated to the patient, plus an ED doctor (if allowed) and the support of an ED nurse.
	Departure type	Included	Included	Not all departure types are included. The GP post includes two end events only, the patient can go home or the patient is referred to the ED. The ED can also send the patient home or admit him/her into the hospital. Other departure types are eliminated due to the limited number.
Room	Capacity	Included	Included	There are six rooms included in the GP post, plus one triage room. Unlimited waiting room capacity. There are twenty-two treatment rooms, and one triage room. Sixteen rooms are dedicated for special treatments. Unlimited waiting room capacity.
	Equipment	Excluded	Excluded	Only the equipment for diagnostic testing need to be requested, all other equipment is made available before a new consult starts.
	Type	Excluded	Included	See Section 3.4. For the GP post there is no need to separate the room types, only one room is reserved for physical triage however. The ED treatment rooms are classified into: a) trauma rooms; b) acute rooms; c) plaster rooms; d) fast-track room and e) regular rooms.
Staff	Availability	Excluded	Excluded	Idle staff members are instantaneously available for a new task. No administrative or supporting tasks included.
	Staff roster	Included	Included	The rosters are important due to large fluctuations within the patient arrival rates per hour, day and week.
	Absenteeism	Excluded	Excluded	Unpredictable input factor, not taken into account
	Processing time	Included	Included	The GP post's durations are reliably stored within the patient records. The processes are modelled as a distribution based on historical data. Travel times are excluded, only the GP visits require additional travel time. GP visit's travel duration does not depend on the patient's physical location, the travel duration is simply generated by a probability function. The ED processing times are based on assumptions due to limited time registrations.
Diagnostics	Capacity	Excluded	Excluded	The number of requests is unlimited.
	Type	Included	Excluded	Multiple diagnostic tests could be requested during a physical GP post consult, but only the X-rays are taken into account due to frequent requests. The ED can also request CT scans, ultrasound, ECG and lab research, all these five tests are frequently applied.
	Processing time	Included	Included	The processing times are based on the historical data of the radiology department. A probability distribution is used for this
	Review	Excluded	Included	The GP post does not have to evaluate the results, the patient is referred to the ED immediately if required. The results are only reviewed at the ED itself, not by the diagnostic employee.

Table 55: An overview of the GP post's and the ED's components that are included within the model's details. The table's layout is inspired by Robinson (2004).

Appendix I – Day factor β_d

The day factor β_d represents the number of daily patient arrivals on day in relation to the average number of patient arrivals of the corresponding week set. Therefore, the day factor can be used to distinguish relative busy and quite operational days from each other. The day factor is determined by dividing the total number of patient arrivals of day d by the average number of daily patient arrivals for set D in the corresponding week w, as given by equation 4.5. The day factors are independently determined for all days present within the available pattern sets D ∈ {Weekdays; Weekend}, because of the different arrival patterns observed.

Equation 4.5

$$\beta_d = \frac{\sum_{\forall h} X_{h,d,w,y}}{\frac{1}{t} \cdot \sum_{\forall h} \sum_{\forall d} X_{h,d,w,y}} \qquad \begin{array}{l} \forall d \in D \\ \forall w \in 0, \dots, 52 \\ \forall y \in 1, \dots, 4 \end{array}$$

The variable $X_{h,d,w,y}$ represents the number of patient that arrived at hour h ∈ 1,…,24 on day d ∈ 1,…,7 during week w ∈ 1,…,52 in the year y ∈ {2014; 2015; 2016; 2017}. The parameter t represents the number of days available within one week, which is therefore equal to t=5 for weekdays and t=2 for weekends. If a holiday is included within week w, the number of days available is reduced for that week.

Several scatter diagrams are made in order to determine if the day factors' samples are independent from each other. The scatter diagrams include the pairs (Xi ; Xi+1) for all i=1,2,…,n-1 observations made for each day factor. The correlation tests revealed that no linear correlation exists between any pair of day factors (Table 56). Therefore, it is plausible to assume that the day factor samples result from some underlying distribution. However, the significant differences between the day factors are investigated in more detail in order to reduce the complexity of the data input.

Period	Day of arrival	GP post correlation	GP post interpretation	ED correlation	ED interpretation
Separated (2014-2015)	**Monday**	+0,032	No linear relation	-0,014	No linear relation
	Tuesday	+0,032	No linear relation	+0,101	No linear relation
	Wednesday	-0,185	No linear relation	-0,056	No linear relation
	Thursday	+0,056	No linear relation	-0,054	No linear relation
	Friday	-0,011	No linear relation	-0,137	No linear relation
	Saturday	-0,122	No linear relation	+0,091	No linear relation
	Sunday	-0,122	No linear relation	+0,091	No linear relation
Integrated (2016-2017)	**Monday**	-0,257	No linear relation	-0,008	No linear relation
	Tuesday	-0,189	No linear relation	+0,245	No linear relation
	Wednesday	+0,059	No linear relation	+0,130	No linear relation
	Thursday	+0,025	No linear relation	-0,051	No linear relation
	Friday	-0,005	No linear relation	+0,021	No linear relation
	Saturday	-0,010	No linear relation	+0,094	No linear relation
	Sunday	-0,009	No linear relation	+0,094	No linear relation

Table 56: Pearson's correlation coefficients corresponding to the GP post's and ED's day factors of patient arrivals.

A paired samples t-test is conducted in order to identify any significant differences between the day factors obtained (Table 57). It can be concluded that the GP post's average arrival rate for Tuesdays, Wednesdays and Thursdays are not significantly different for the separated out-of-hours emergency care (Table 58). Therefore, the day factor for these three days is determined altogether in order to reduce the simulation model's data input. All other day factors are significantly different from each other. The Mondays are even added to the "midweek" cluster since the integration of the GP post and the ED since the 11th of January (Table 59).

GP post's daily factor statistics	Non-integrated emergency care (2014-2015)				Integrated emergency care (2016-2017)			
	Mean	N	Std. Deviation	Std. Error Mean	Mean	N	Std. Deviation	Std. Error Mean
Monday factor	82,189	90	12,889	1,359	0,984	90	0,100	0,011
Tuesday factor	79,522	90	10,535	1,111	0,973	90	0,096	0,010
Wednesday factor	77,900	90	10,551	1,112	0,970	90	0,085	0,009
Thursday factor	78,811	90	10,105	1,065	0,956	90	0,090	0,010
Friday factor	93,256	90	11,479	1,210	1,117	90	0,107	0,011
Saturday factor	1,076	100	0,051	0,005	1,060	96	0,043	0,004
Sunday factor	0,924	100	0,051	0,005	0,940	96	0,043	0,004

Table 57: Descriptive statistics corresponding to the daily factors of the GP post's patient arrivals during the non-integrated (2014-2015) and the integrated emergency care organization (2016-2017).

GP post day factor non-integrated organization (2014-2015)		Paired Samples Test: Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Monday factor - Tuesday factor	2,667	16,222	1,710	-0,731	6,064	1,56	89	0,122
Pair 2	Monday factor - Wednesday factor	4,289	14,711	1,551	1,208	7,370	2,77	89	0,007
Pair 3	Monday factor - Thursday factor	3,378	13,789	1,454	0,490	6,266	2,32	89	0,022
Pair 4	Monday factor - Friday factor	-11,067	15,806	1,666	-14,377	-7,756	-6,64	89	0,000
Pair 5	Tuesday factor - Wednesday factor	1,622	12,234	1,290	-0,940	4,185	1,26	89	0,212
Pair 6	Tuesday factor - Thursday factor	0,711	13,597	1,433	-2,137	3,559	0,50	89	0,621
Pair 7	Tuesday factor - Friday factor	-13,733	14,156	1,492	-16,698	-10,768	-9,20	89	0,000
Pair 8	Wednesday factor - Thursday factor	-0,911	13,199	1,391	-3,676	1,853	-0,65	89	0,514
Pair 9	Wednesday factor - Friday factor	-15,356	14,343	1,512	-18,360	-12,352	-10,16	89	0,000
Pair 10	Thursday factor - Friday factor	-14,444	11,663	1,229	-16,887	-12,002	-11,75	89	0,000
Pair 11	Saturday factor - Sunday factor	0,152	0,102	0,010	0,132	0,172	14,93	99	0,000

Table 58: Paired sample t-test for the GP post's daily factors of all weekdays during the separated out-of-hours emergency care organization (2014-2015), including a significance level of alpha = 0.05. Significantly different daily factors are yellow marked (sigma < 0.05). Weeks including missing values are eliminated, due to holidays for example. The average arrival rates for Tuesdays, Wednesdays and Thursdays are not significantly different from each other.

GP post day factor integrated organization (2016-2017)		Paired Samples Test: Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Monday factor - Tuesday factor	0,011	0,159	0,017	-0,023	0,044	0,64	89	0,526
Pair 2	Monday factor - Wednesday factor	0,013	0,144	0,015	-0,017	0,043	0,87	89	0,386
Pair 3	Monday factor - Thursday factor	0,028	0,149	0,016	-0,004	0,059	1,75	89	0,083
Pair 4	Monday factor - Friday factor	-0,133	0,167	0,018	-0,168	-0,098	-7,56	89	0,000
Pair 5	Tuesday factor - Wednesday factor	0,003	0,136	0,014	-0,026	0,031	0,18	89	0,857
Pair 6	Tuesday factor - Thursday factor	0,017	0,150	0,016	-0,014	0,048	1,07	89	0,288
Pair 7	Tuesday factor - Friday factor	-0,144	0,161	0,017	-0,178	-0,110	-8,51	89	0,000
Pair 8	Wednesday factor - Thursday factor	0,014	0,134	0,014	-0,014	0,042	1,01	89	0,314
Pair 9	Wednesday factor - Friday factor	-0,147	0,159	0,017	-0,180	-0,113	-8,77	89	0,000
Pair 10	Thursday factor - Friday factor	-0,161	0,156	0,016	-0,194	-0,128	-9,80	89	0,000
Pair 11	Saturday factor - Sunday factor	0,120	0,086	0,009	0,103	0,138	13,66	95	0,000

Table 59: Paired sample t-test for the GP post's daily factors of all weekdays during the integrated out-of-hours emergency care organization (2016-2017), including a significance level of alpha = 0.05. Significantly different daily factors are yellow marked (sigma < 0.05). Weeks including missing values are eliminated, due to holidays for example. The average arrival rates for Mondays, Tuesdays, Wednesdays and Thursdays are not significantly different from each other.

The same paired samples t-test is conducted for the ED's daily arrival factors obtained (Table 60). Three different clusters can be formed for the separated out-of-hours emergency care organization (Table 61)), including daily arrival factors that are not significantly different: 1) Monday & Friday; 2) Wednesday & Thursday and finally 3) Saturday & Sunday. The daily arrival factors changed however since the integration of the GP post and the ED (Table 62), resulting in two clusters: 1) Monday & Friday and 2) Tuesday & Wednesday.

ED daily factor statistics	Non-integrated emergency care (2014-2015)				Integrated emergency care (2016-2017)			
	Mean	N	Std. Deviation	Mean	Mean	N	Std. Deviation	Mean
Monday factor	1,074	90	0,099	0,010	1,068	90	0,102	0,011
Tuesday factor	0,926	90	0,090	0,009	0,946	90	0,112	0,012
Wednesday factor	0,979	90	0,102	0,011	0,961	90	0,096	0,010
Thursday factor	0,970	90	0,097	0,010	0,986	90	0,095	0,010
Friday factor	1,052	90	0,099	0,010	1,040	90	0,104	0,011
Saturday factor	1,014	100	0,096	0,010	67,833	96	9,486	0,968
Sunday factor	0,986	100	0,096	0,010	63,229	96	9,576	0,977

Table 60: Descriptive statistics corresponding to the daily factors of the ED's patient arrivals during the non-integrated (2014-2015) and the integrated emergency care organization (2016-2017).

ED day factor integrated organization (2016-2017)		Paired Samples Test: Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Monday factor - Tuesday factor	0,148	0,140	0,015	0,118	0,177	9,99	89	0,000
Pair 2	Monday factor - Wednesday factor	0,095	0,161	0,017	0,061	0,129	5,62	89	0,000
Pair 3	Monday factor - Thursday factor	0,104	0,156	0,016	0,071	0,136	6,29	89	0,000
Pair 4	Monday factor - Friday factor	0,022	0,162	0,017	-0,012	0,056	1,30	89	0,197
Pair 5	Tuesday factor - Wednesday factor	-0,053	0,150	0,016	-0,084	-0,021	-3,34	89	0,001
Pair 6	Tuesday factor - Thursday factor	-0,044	0,146	0,015	-0,075	-0,014	-2,88	89	0,005
Pair 7	Tuesday factor - Friday factor	-0,126	0,156	0,016	-0,158	-0,093	-7,67	89	0,000
Pair 8	Wednesday factor - Thursday factor	0,008	0,165	0,017	-0,026	0,043	0,49	89	0,626
Pair 9	Wednesday factor - Friday factor	-0,073	0,155	0,016	-0,105	-0,040	-4,46	89	0,000
Pair 10	Thursday factor - Friday factor	-0,081	0,148	0,016	-0,112	-0,050	-5,21	89	0,000
Pair 11	Saturday factor - Sunday factor	1,760	14,091	1,409	-1,036	4,556	1,25	99	0,215

Table 61: Paired sample t-test for the ED's daily factors of all weekdays during the separated out-of-hours emergency care organization (2014-2015), including a significance level of alpha = 0.05. Significantly different daily factors are yellow marked (sigma < 0.05). Weeks including missing values are eliminated, due to holidays for example. Three clusters can be formed including daily arrival factors that are not significantly different: 1) Monday & Friday; 2) Wednesday & Thursday and finally 3) Saturday & Sunday.

ED day factor integrated organization (2016-2017)		Paired Samples Test: Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Monday factor - Tuesday factor	0,121	0,174	0,018	0,085	0,158	6,60	89	0,000
Pair 2	Monday factor - Wednesday factor	0,107	0,143	0,015	0,077	0,137	7,13	89	0,000
Pair 3	Monday factor - Thursday factor	0,082	0,159	0,017	0,049	0,116	4,91	89	0,000
Pair 4	Monday factor - Friday factor	0,028	0,168	0,018	-0,007	0,063	1,59	89	0,116
Pair 5	Tuesday factor - Wednesday factor	-0,014	0,169	0,018	-0,049	0,021	-0,80	89	0,427
Pair 6	Tuesday factor - Thursday factor	-0,039	0,166	0,017	-0,074	-0,004	-2,24	89	0,028
Pair 7	Tuesday factor - Friday factor	-0,093	0,168	0,018	-0,129	-0,058	-5,26	89	0,000
Pair 8	Wednesday factor - Thursday factor	-0,025	0,149	0,016	-0,056	0,006	-1,59	89	0,116
Pair 9	Wednesday factor - Friday factor	-0,079	0,163	0,017	-0,113	-0,045	-4,59	89	0,000
Pair 10	Thursday factor - Friday factor	-0,054	0,150	0,016	-0,086	-0,023	-3,42	89	0,001
Pair 11	Saturday factor - Sunday factor	4,604	11,180	1,141	2,339	6,870	4,03	95	0,000

Table 62: Paired sample t-test for the ED's daily factors of all weekdays during the integrated out-of-hours emergency care organization (2016-2017), including a significance level of alpha = 0.05. Significantly different daily factors are yellow marked (sigma < 0.05). Weeks including missing values are eliminated, due to holidays for example. Two clusters can be formed including daily arrival factors that are not significantly different: 1) Monday & Friday and 2) Tuesday & Wednesday.

A probability function is fitted to the arrival data for each set of days found by the paired sample t-tests. These estimated probability functions will be used to generate the day factor required within the simulation model. *Table 11* visualizes all the estimated probability functions resulting from the Chi squared tests applied within the simulation software *"Technomatix Plant Simulation"*. It can be concluded that all day factors can be described by either the normal, lognormal, weibull or gamma distribution. All these functions require two parameters only in order to describe the patient's arrival process, which is far less in comparison with the empirical observations made. Figure 67, Figure 68, Figure 69 and Figure 70 visualize the day factors' histograms used during the data fitting processes.

Organization type	Day(s) of the week	# bins Sturges's rule	Lower bound	Upper bound	Distribution	Chi statistic	Chi value	Parameter 1	Parameter 2
Separated GP post (2014-2015)	Monday	7	0,8	∞	Lognorm	2,21	5,98	1,01	0,09
	Tuesday, Wednesday & Thursday	9	-∞	∞	Lognorm	7,36	11,06	0,96	0,10
	Friday	7	-∞	∞	Lognorm	6,70	9,48	1,13	0,11
	Saturday	7	-∞	∞	Normal	6,16	9,48	1,08	0,05
	Sunday	7	-∞	∞	Normal	6,16	9,48	0,92	0,05
Integrated GP post (2016-2017)	Monday, Tuesday, Wednesday & Thursday	9	0,7	∞	Lognorm	5,75	11,06	0,97	0,09
	Friday	7	-∞	∞	Weibull	0,69	9,48	12,11	1,16
	Saturday	7	-∞	∞	Normal	1,85	9,48	1,06	0,04
	Sunday	7	-∞	∞	Normal	1,85	9,48	0,94	0,04
Separated ED (2014-2015)	Monday & Friday	8	-∞	∞	Normal	4,56	11,06	1,06	0,10
	Tuesday	7	-∞	∞	Normal	3,03	9,48	0,93	0,09
	Wednesday & Thursday	8	-∞	∞	Normal	3,13	11,06	0,97	0,10
	Saturday & Sunday	8	-∞	∞	Lognorm	1,51	9,48	1,00	0,10
Integrated ED (2016-2017)	Monday & Friday	8	-∞	∞	Lognorm	2,74	9,48	1,05	0,10
	Tuesday & Wednesday	8	-∞	∞	Gamma	3,22	9,48	83,15	0,01
	Thursday	7	-∞	∞	Weibull	1,93	9,48	11,28	1,03
	Saturday	7	-∞	∞	Lognorm	0,38	5,98	1,04	0,09
	Sunday	7	-∞	∞	Lognorm	0,73	5,98	0,96	0,09

Table 63: Estimated probability functions underlying the GP post's and ED's daily arrival factors. These factors are determined for the separated and integrated out-of-hours emergency care organization. Two parameters are required to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ), while the "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β).

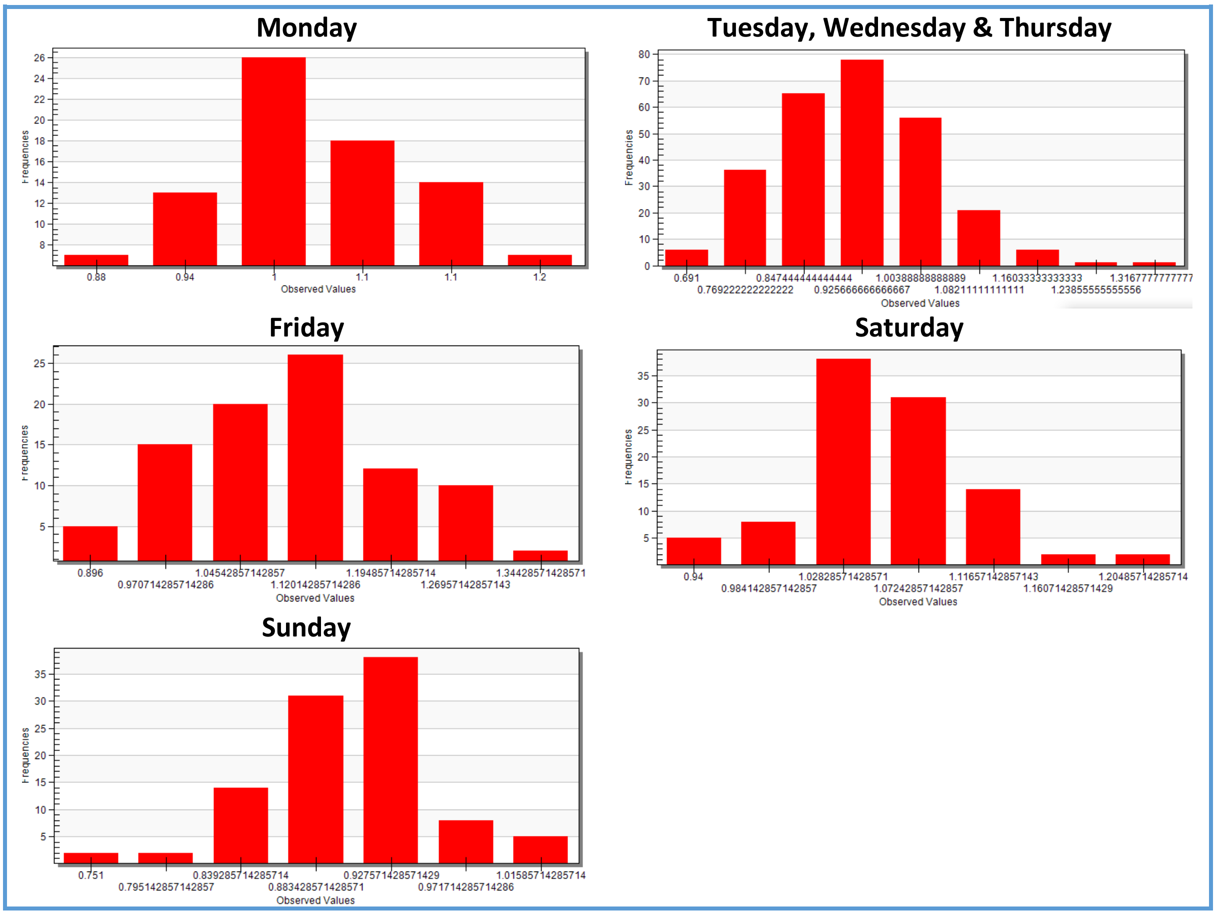


Figure 67: Histograms representing the GP post's day factor distributions between 2014 and 2015.

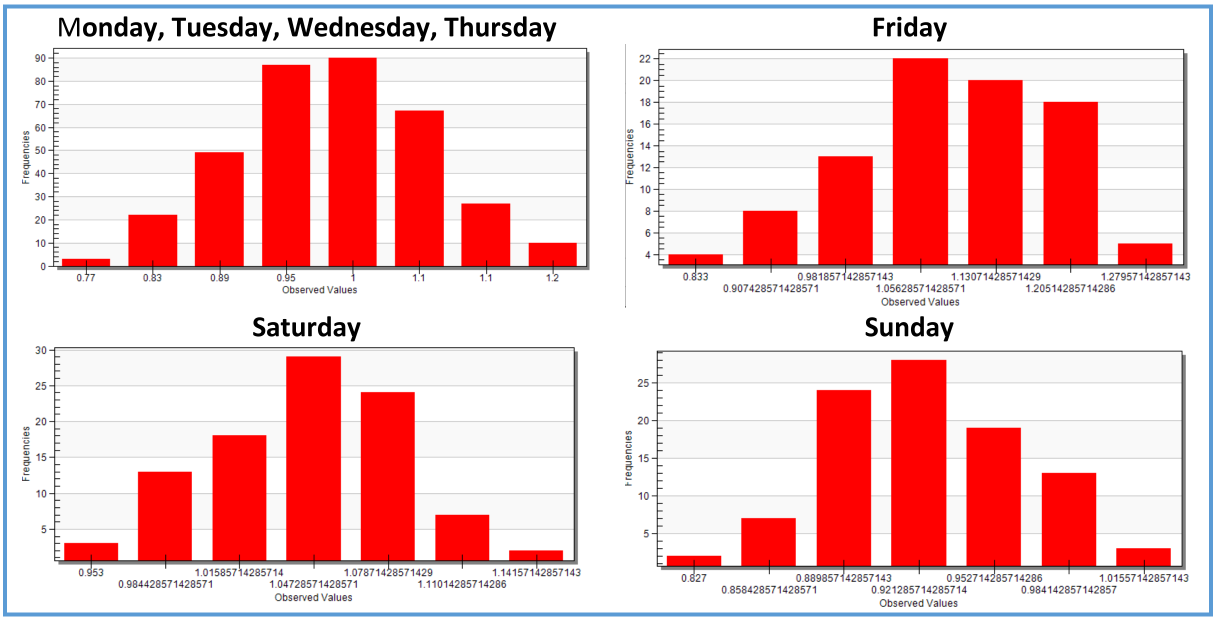


Figure 68: Histograms representing the GP post's day factor distributions between 2016 and 2017.

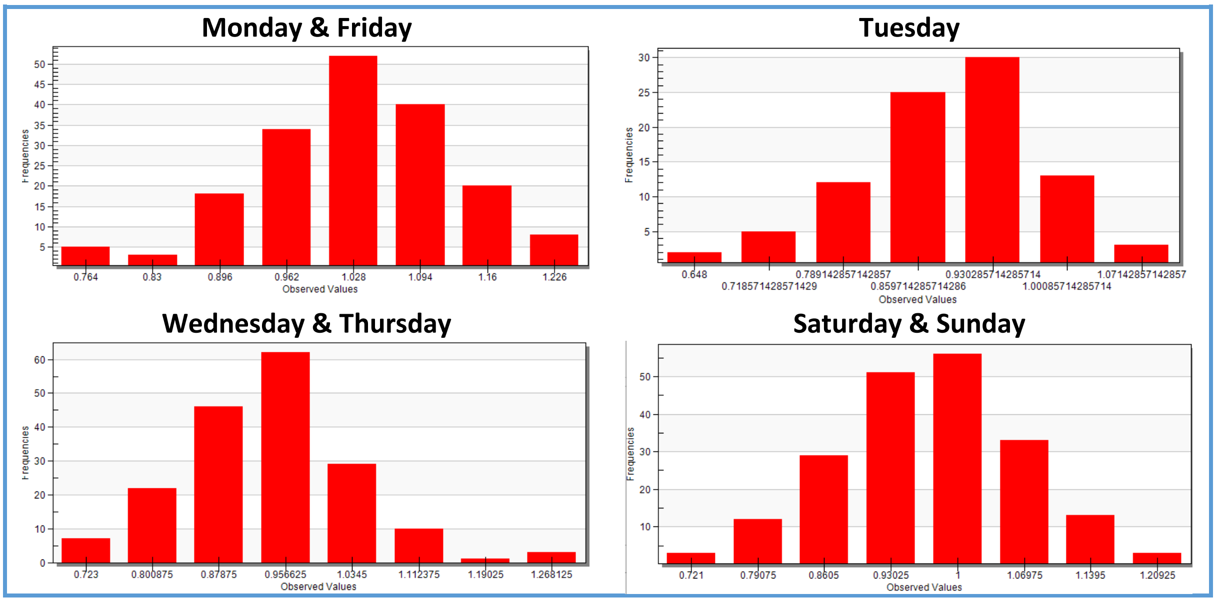


Figure 69: Histogram representing the ED's day factor distributions between 2014 and 2015.

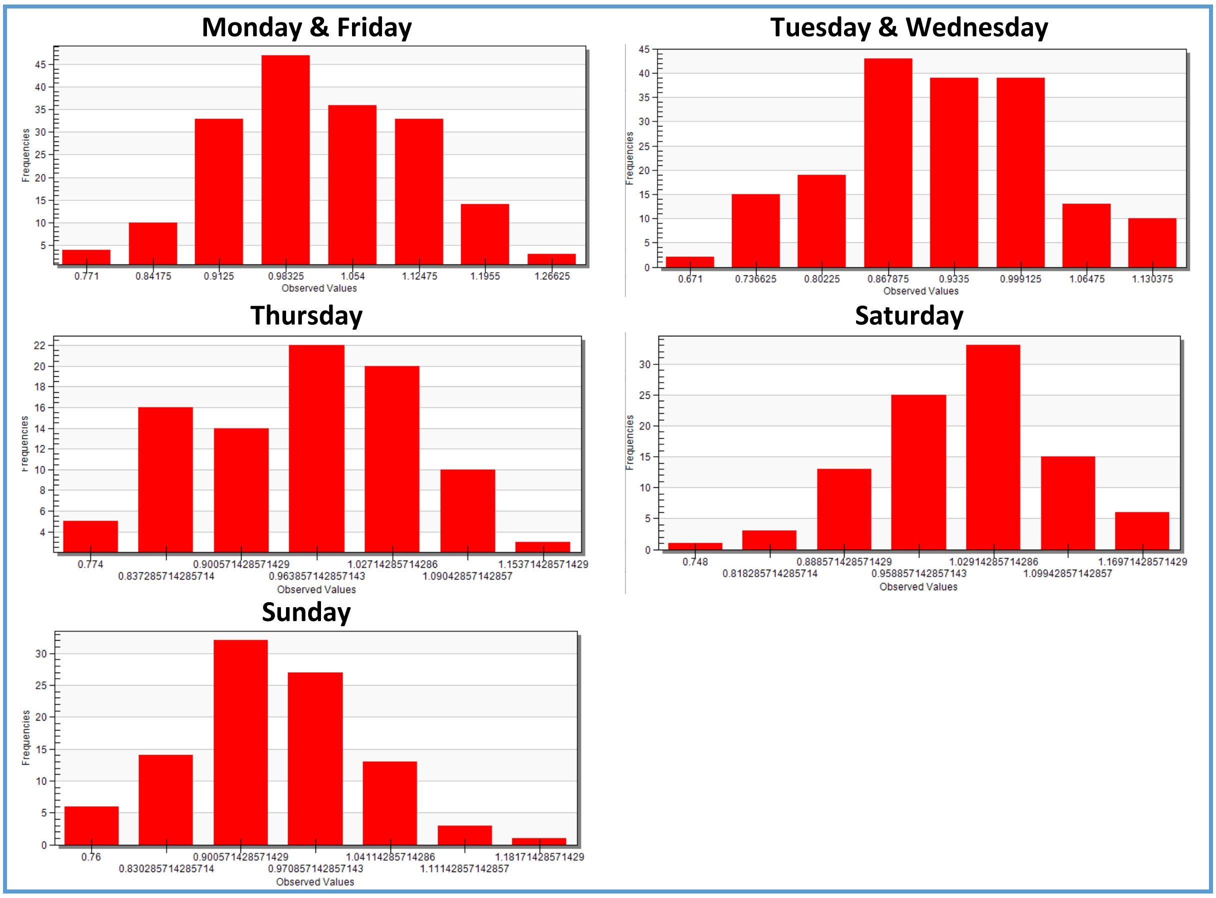


Figure 70: Histogram representing the ED's day factor distributions between 2016 and 2017.

Appendix J – Week factor Υ_w distributions

The week factor Υ_w represents the number of weekly patient arrivals in relation to the average number of patient arrivals of the corresponding year. Therefore, the week factor can be used to distinguish relative busy and quite operational weeks from each other. The week factor is determined by dividing the total number of patient arrivals of week w by the average number of daily patient arrivals in the corresponding year y, as given by equation 4.6.

Equation 4.6

$$\beta_{w,y} = \frac{\sum_{\forall h} \sum_{\forall d} X_{h,d,w,y}}{\frac{1}{t} \cdot \sum_{\forall h} \sum_{\forall d} \sum_{\forall w} X_{h,d,w,y}} \qquad \begin{array}{l} \forall w \in 0, \dots, 52 \\ \forall y \in 1, \dots, 4 \end{array}$$

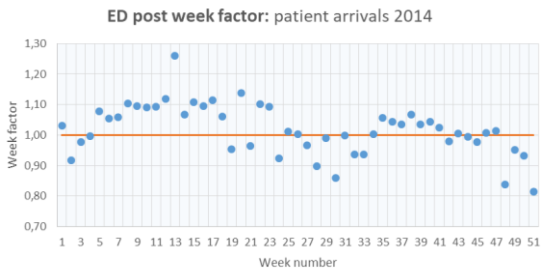
The variable $X_{h,d,w,y}$ represents the number of patient that arrived at hour h ∈ 1,…,24 on day d ∈ 1,…,7 during week w ∈ 1,…,52 in the year y ∈ {2014; 2015; 2016; 2017}. The parameter t represents the number of weeks available within one year, which is therefore equal to t=52. The week factors' distributions are visualized by Figure 71 and Figure 72 for the GP post and the ED respectively.

a) GP post week factor distribution 2014 *d) GP post week factor distribution 2016*

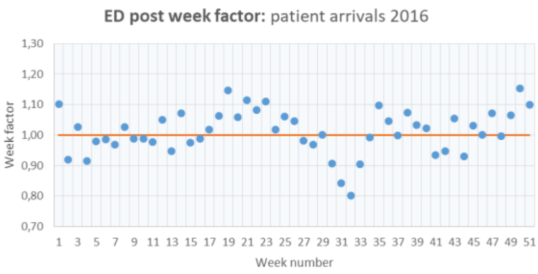
b) GP post week factor distribution 2015 *e) GP post week factor distribution 2017*

c) Separated GP post week factor distribution *f) Integrated GP post week factor distribution*

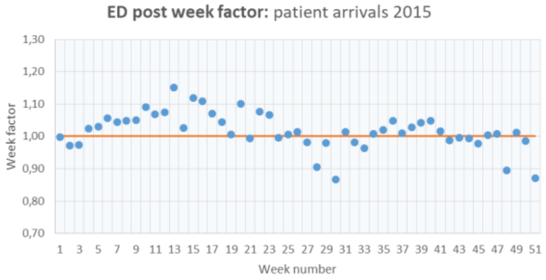
Figure 71: GP post week factor distributions for each year. Figure c) and f) include the average week factors for two years.



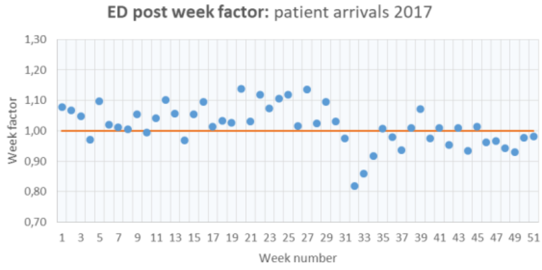
a) ED week factor distribution 2014



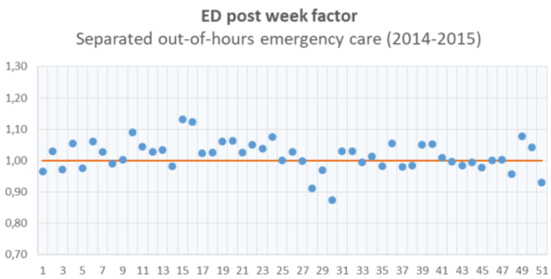
d) ED week factor distribution 2016



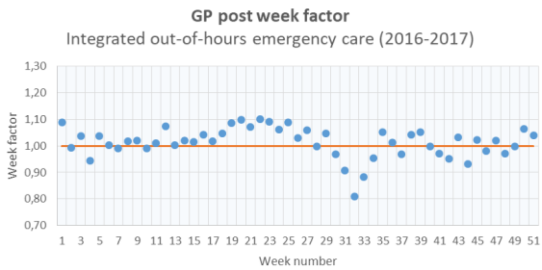
b) ED week factor distribution 2015



e) ED week factor distribution 2017



c) Separated ED week factor distribution



f) Integrated ED week factor distribution

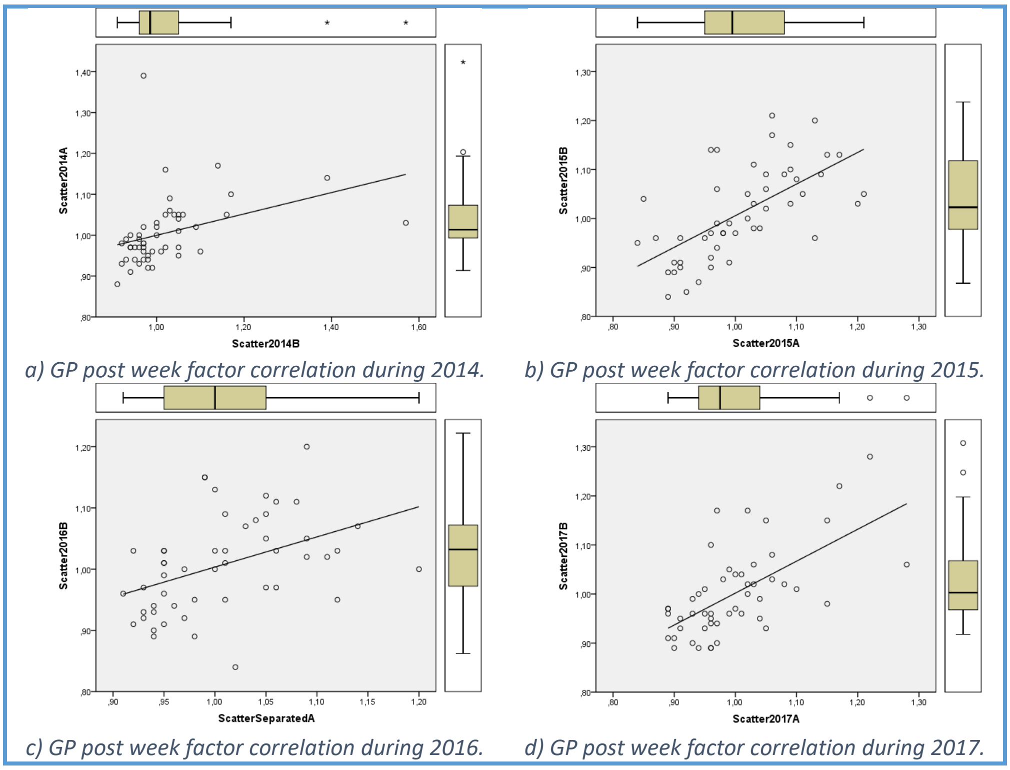
Figure 72: ED's week factor distributions for each year. Figure c) and f) include the average week factors for two years.

A correlation analysis of the week factors $\beta_{w,y}$ revealed that the samples are not completely independent from each other (Table 64). Two pairs of successive weeks of GP patient arrivals are plotted in a scatter diagram in order to find a linear correlation. For example, if the number of patients in week i is relatively high, than there is a moderate probability that week i+1 also faces a lot of patient arrivals. The correlation analysis is conducted for all arrival years separately, but also for the week average during the separated and integrated out-of-hours emergency care organization. Finally, the same analysis is repeated for all records successively.

Most pairs of successive weeks of GP patient arrivals are moderately and positively correlated. For example, if the number of patients in week i is relatively high, than there is a moderate probability that week i+1 also faces a lot of patient arrivals. Two pairs of successive weeks including ED patient arrivals is less correlated, but there is still a significant linear relationship found. The linear relationships are visualized for both for the GP post (*Figure 73*) and the ED (*Figure 74*) per year. Most scatter plots represent a moderate correlation coefficient, which indicates that the weekly patient arrivals are not independent from each other. The same observations result from the week averages per period (*Figure 75*) and the serial data records per period (*Figure 76*).

Period	GP post correlation	GP post Interpretation	ED correlation	ED Interpretation
2014	+0,356	Weak positive	+0,444	Weak positive
2015	+0,633	Moderate positive	+0,167	No linear relationship
2016	+0,553	Moderate positive	+0,467	Weak positive
2017	+0,628	Moderate positive	+0,476	Weak positive
Separated – week average	+0,550	Moderate positive	+0,457	Weak positive
Integrated week average	+0,696	Moderate positive	+0,525	Moderate positive
All data – week average	+0,710	Strong positive	+0,547	Moderate positive
Separated – serial records	+0,407	Weak positive	+0,378	Weak positive
Integrated – serial records	+0,595	Moderate positive	+0,479	Weak positive
All data – serial records	+0,468	Weak positive	+0,419	Weak positive

Table 64: Pearson's correlation coefficients for the week factors obtained within the GP post and the ED during the period 2014-2017. The coefficients are based on the scatter diagrams of the pairs (X_i ; X_{i+1}) for all i=1,2,…,n-1 observations.

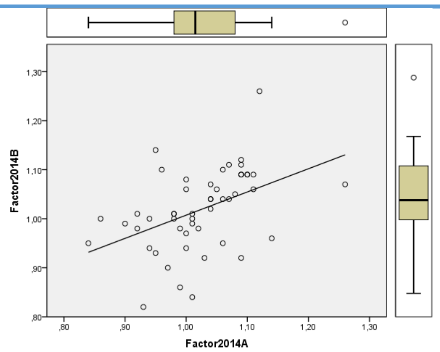


a) GP post week factor correlation during 2014. *b) GP post week factor correlation during 2015.*

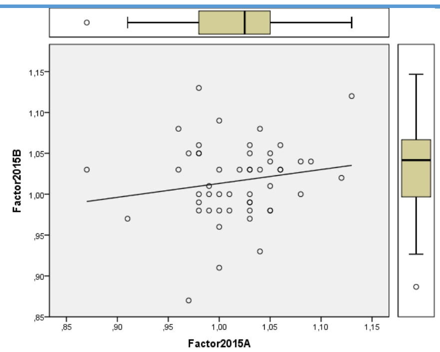
c) GP post week factor correlation during 2016. *d) GP post week factor correlation during 2017.*

Figure 73: GP post's week factor scatter diagrams for each year individually.

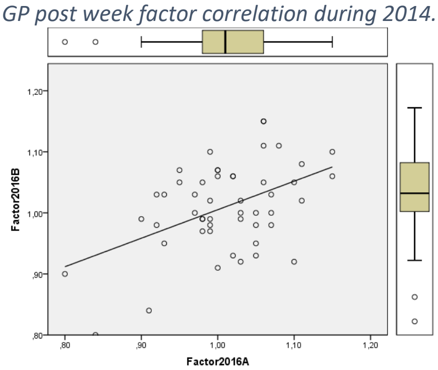
Figure 77 visualizes GP post's and ED's average week factors for the whole period between 2014 and 2017. The presence of holidays result in some GP post's patient arrival peaks during the spring and during the year's last week. The GP post faces relatively more patients during the first half of the year, the number of patient arrivals drops after the summer break. The same pattern is observed by the ED, but with less significance. The ED mainly faces a large drop of patient arrivals during the summer break.



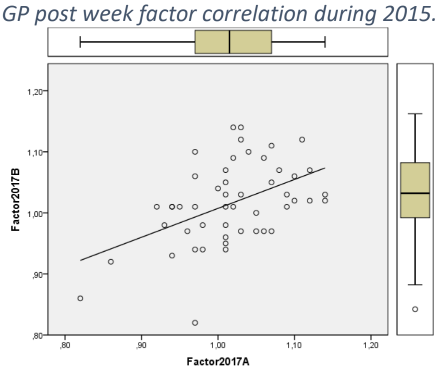
a) GP post week factor correlation during 2014.



b) GP post week factor correlation during 2015.

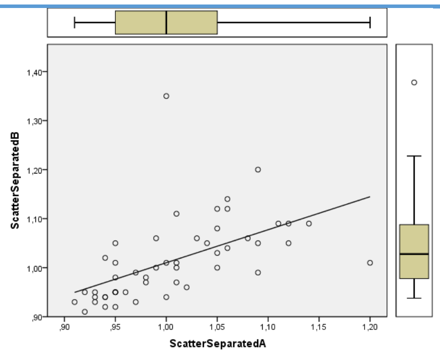


c) GP post week factor correlation during 2016.

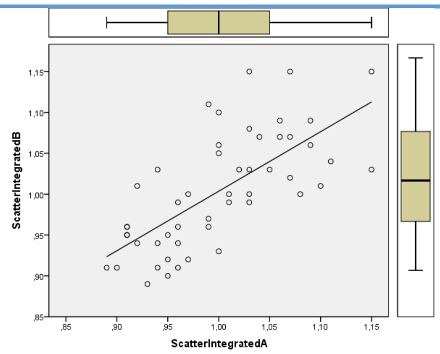


d) GP post week factor correlation during 2017.

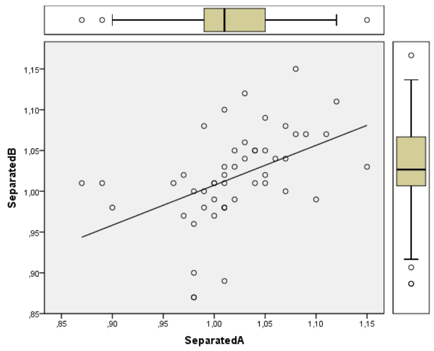
Figure 74: ED post's week factor scatter diagrams for each year individually.



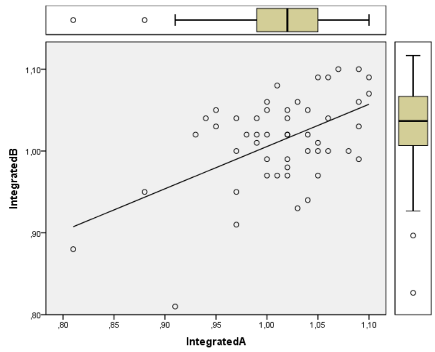
a) GP post week factor correlation (2014-2015)



b) GP post week factor correlation (2016-2017)

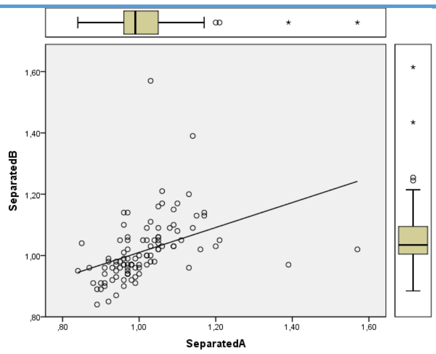


c) ED week factor correlation (2016-2017)

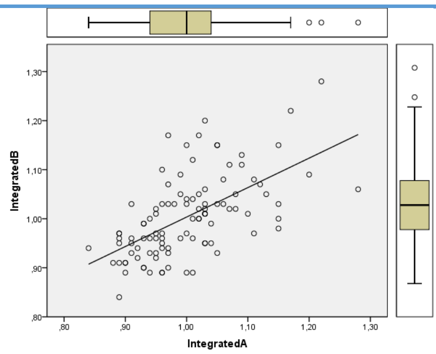


d) ED week factor correlation (2016-2017)

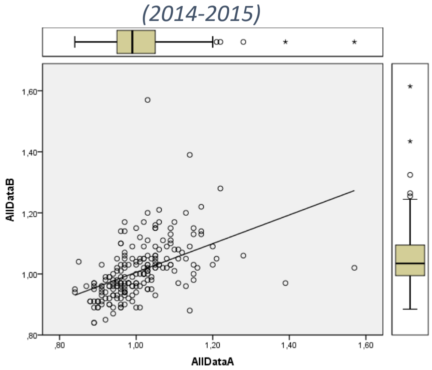
Figure 75: Scatter diagrams of the GP post and ED weekly patient average arrivals per year.



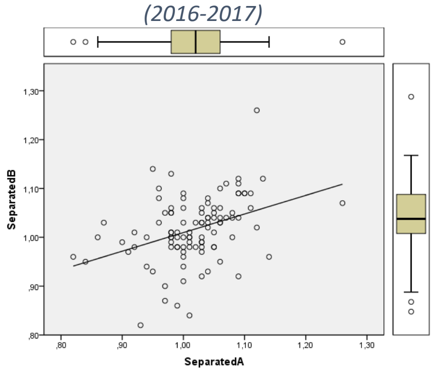
a) Serial GP post week factor correlation (2014-2015)



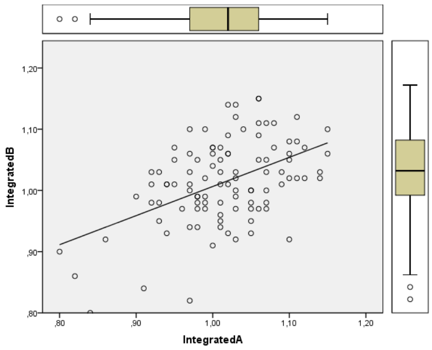
b) Serial GP post week factor correlation (2016-2017)



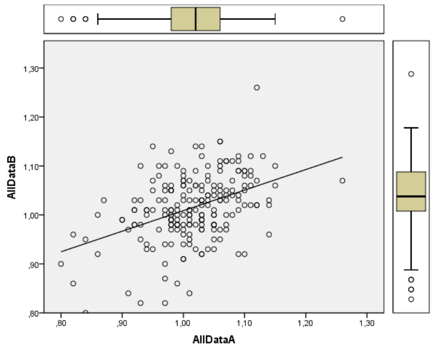
c) Serial GP post week factor correlation (2014-2017)



d) Serial ED week factor correlation (2014-2015)

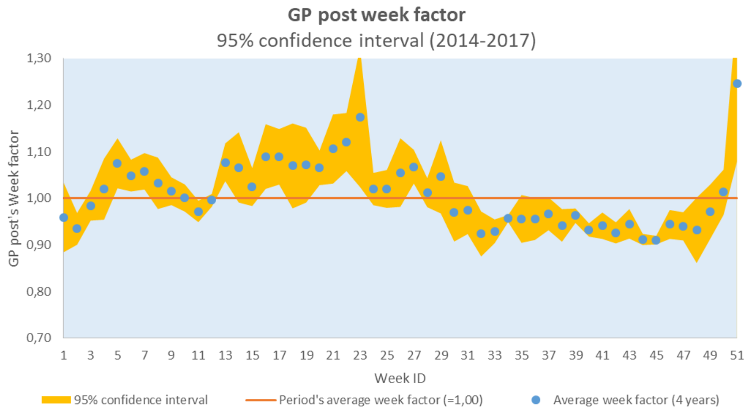


e) Serial ED week factor correlation (2016-2017)

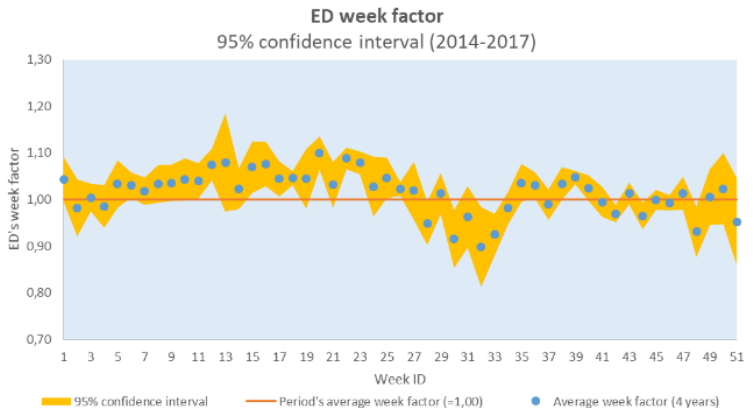


f) Serial ED week factor correlation (2014-2017)

Figure 76: Scatter diagrams of the GP post and ED weekly patient serial arrivals per period.



a) GP post's week factor distribution.



b) ED's week factor distribution.

Figure 77: 95% confidence intervals of the week factor's mean for the GP post and ED within the period 2014-2017.

The confidence intervals in *Figure 77* reveal a repeating pattern, but the relationship is not too strong in order to speak of seasonality. Most correlation coefficients indicate a moderate relationship, which results in relatively small fluctuations of the GP post's and ED's week factors. Therefore, it is assumed that the week factor samples are independent from each other. *Table 12* provides an overview of the probability functions underlying the empirical week factor samples.

Organization type	# bins Sturges's rule	Lower bound	Upper bound	Distribution	Chi statistic	Chi value	Parameter 1	Parameter 2
Separated GP post (2014-2015)	7	-∞	∞	Lognorm	6,21	9,48	1,00	0,08
Integrated GP post (2016-2017)	7	-∞	∞	Normal	1,36	9,48	1,00	0,08
Separated ED (2014-2015)	7	-∞	∞	Normal	5,61	9,48	1,02	0,07
Integrated ED (2016-2017)	7	-∞	∞	Normal	1,22	9,48	1,01	0,07

Table 65: Estimated probability functions underlying the GP post's and ED's weekly arrival factors. These factors are determined for the separated and integrated out-of-hours emergency care organization. Only two parameters are required to describe the "normal" and "lognormal" distribution, the mean (μ) and standard deviation (σ).

Appendix P – The simulation model

A simulation model is used within this research in order to evaluate the performances of the out-of-hours emergency care in Enschede. Chapter 4 prescribes how the real world is translated into a conceptual model. The development of a conceptual model allowed the creation of a simulation model in the software package “Technomatix Plant Simulation”. This appendix will discuss all the simulation model’s elements in more detail.

P.1. Model elements

Plant simulation is a software package for integrated, graphic an object-oriented modelling, simulation and animation (Mes, 2016). The desktop interface consists of four main structures ():

1. **Class library:** a structured view of all object classes available in the current model. The object classes are stored in hierarchal order;
2. **Console:** this window provides the end-user with information about the execution of the simulation itself;
3. **Toolbox:** an alternative view of the available object classes which can be customized by the end-user;
4. **Root frame:** the main frame which include all objects that build up the simulation model.

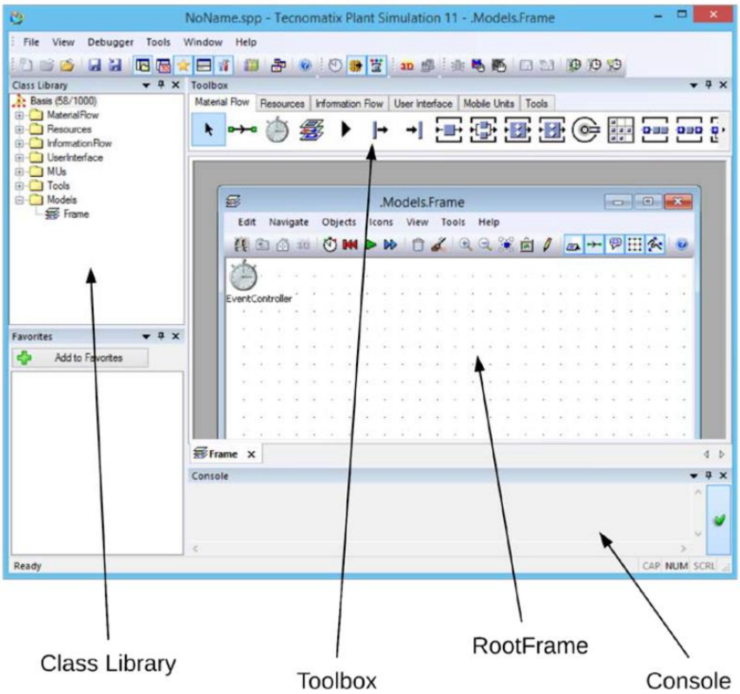


Figure 78: A visualization of the desktop interface used in the software "Technomatix Plant Simulation" (Mes, 2016).

The simulation model is developed by dragging multiple class objects into the main frame. Several alternative class objects are made available for the end-user to insert, each with its own function:

1. **Material Flow:** all objects aimed for the transportation, processing and/or storage of other moving units (MUs);
2. **Resource:** all objects incorporating the allocation of human resources to the processes;
3. **Information Flow:** all objects regarding the gathering, storage, modification and/or retrieval of data and information. This section includes variables, table files and methods ensuring the data exchange between other objects;

4. **User Interface:** Objects suitable for the end-user to make the interface more user-friendly;
5. **Mobile Units:** all moving units (MU) that pass along the other objects, mainly material flow objects;
6. **User objects:** the user can decide to implement one or more frames into the model's main frame, allowing the user to make use of object oriented programming;
7. **Tools:** this section includes some pre-programmed tools which the user can use to apply, like experimental tools that can be used in order to investigate alternative process designs automatically.

Koster (2014) and previous model builders made use of a very limited number of alternative objects in order to maintain the simulation model generally applicable to other hospital settings. Table 66 provides an overview of all the objects most frequently used within the simulation model.

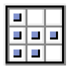
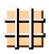
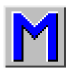
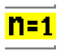
Icon	Object name	Description
	Frame	The frame serves for grouping objects and to build hierarchically structured models by inserting any of the built-in objects or any objects the user designs.
	Store	The store stores any number of MUs the user defines. The MUs remain in the store until the unit is removed by any user control. The stores are used to represent the different types of rooms available within the IEP Enschede.
	Entity or Moving Unit	The entity is a moving matieral flow object without loading capacity that is moved around the material flow objects. The patients are represented by entities, which include multiple attributes in order to describe the patient's characteristics simulated.
	Method	The method enables the modeler to program any decision logic into the model. The decision logic controls the activation and/or movement of other objects within the simulation model. The software makes use of the programming language "SimTalk".
	Variable	A global variable that can store any type of information. Other objects and methods can access or modify the variable during a simulation run.
	Table file	A two-dimensional data container that can store any type of information. the table file's dimension, data types and information included can be retrieved, modified or removed at any time, even during a simulation run.
	Comment	An useful interface element that allows the programmer to store additional information into the frames.

Table 66: Explanation of the simulation model's object most frequently used by Koster (2014) and previous model developers. The definitions are inspired by the software's help function and the tutorial developed by Mes (2016).

P.2. The simulation's logic

The flow chart in *Figure 79* visualizes the decision logic that triggers decisions and processes once an event occurs (Mes & Bruens, 2012). The activities of the patients' logistic care paths are represented by tasks. A new task is created once a patient arrives at the IEP or the patient's previous task is finished. All tasks are gathered into the task list. The tasks are first prioritized first and evaluated secondly one-by-one in order to verify if all required resources are available. If the patient and all resources are available and no delays are required (like travel time or waiting for diagnostic test results), the task is activated and the patient will be treated.

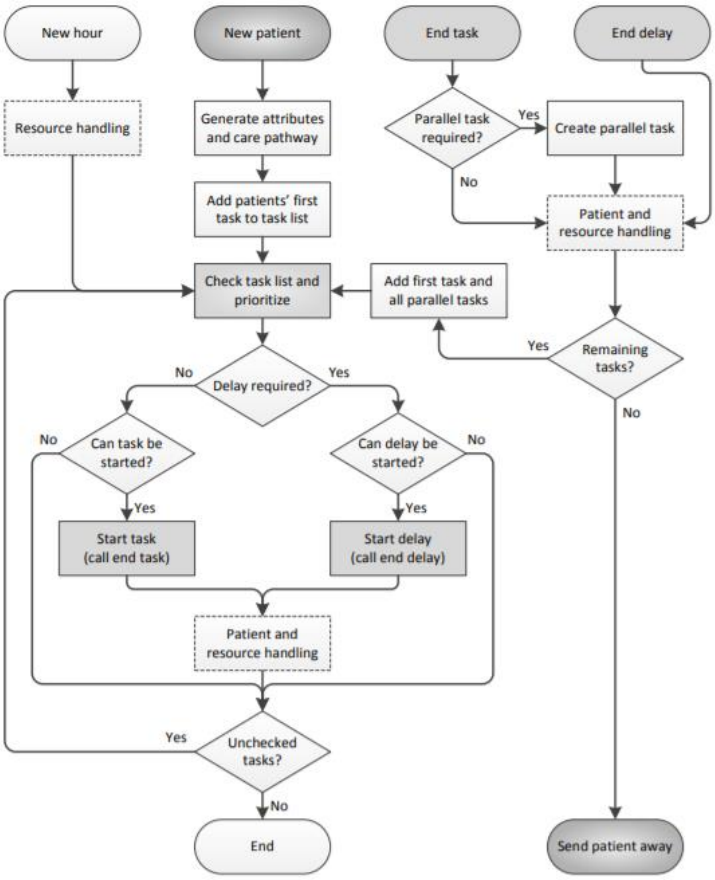


Figure 79: The simulation framework proposed by Mes & Bruens (2012).

P.3. The "MainModel" frame

The main frame is used as main menu within the simulation's graphical user interface. Once the user opens the simulation software, the "MainModel" frame is displaced first. The main frame include some controls which allow the user to activate, pause or exit the simulation experiments. The main frame also includes all other frames used for the simulation, which can be opened by clicking on the buttons located at the "MainModel" frame. Each frame included has its own unique purpose:

1. **Map**: the main frame used for the simulation's animation.
2. **Info:** information about the simulation's progress is stored within the "Info" frame. This frame also includes the key decision logic required in order to describe the IEP's processes;
3. **EventController**: The simulation model's timing routine, including the event list and several interfaces that allow the user to modify the simulation's progress.
4. **Basic:** this frame includes the decision logic required for the creation of the discrete events. This frame is mainly concerned with the creation of patient arrivals and the initialization of new batches.
5. **Settings**: this frame is used to insert the simulation model's input variables.
6. **Performance:** the output variables (KPIs) are stored within the table files of the "Performance" frame.
7. **Experiments:** this frame is for the creation of new experiments. The methods included within this frame will change the simulation model's configurations automatically once the experiments are activated.

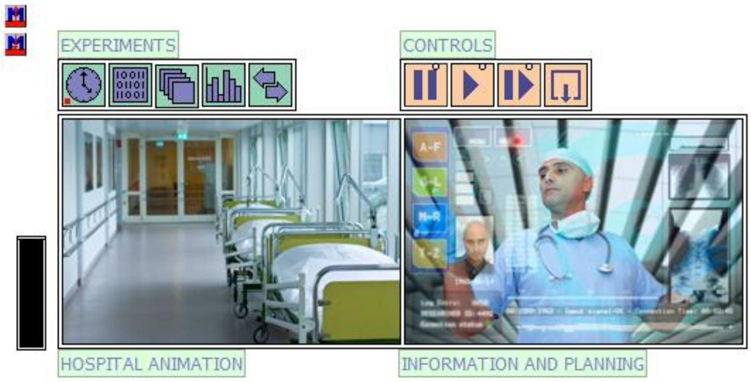


Figure 80: Visualization of the "MainModel" frame, which is used as graphical user interface in order to link all other frames.

P.4. The “Map” frame

The “Map” is the main frame used for the simulation’s animation. The frame includes a building layout of the IEP Enschede (Figure 81), which represents all rooms available in the GP post and the ED. This frame is mainly used to visualize the movements of patients, staff and other resources within the IEP Enschede. The visualizations enable the user to identify and verify the logistic performances resulting from the configuration simulated.

The “Store” object is mainly used to build up the “Map” frame, which represents a specific type of room within the IEP Enschede. This material flow object enables the simulation model to store any number of movable units. Therefore, the patient’s care path can be simulated by bringing the patient, staff and resources required together into one store. The “Map” frame also includes an “Init” and “Reset” method, which remain unused however.

Figure 81: Visualization of the "Map" frame. This frame is mainly used to visualize the movements of patients, staff and other resources within the IEP Enschede.

P.5. The “Info” frame

P.5.1. The frame’s purposes

The “Info” frame forms the main part of the simulation model’s framework (Figure 82). This frame includes all methods required for the patient and resource handling activities. New attributes are generated for all newly arriving patients. All patients are prioritized in a task list for further treatment. The frame also includes table files including information about the simulation’s progress.

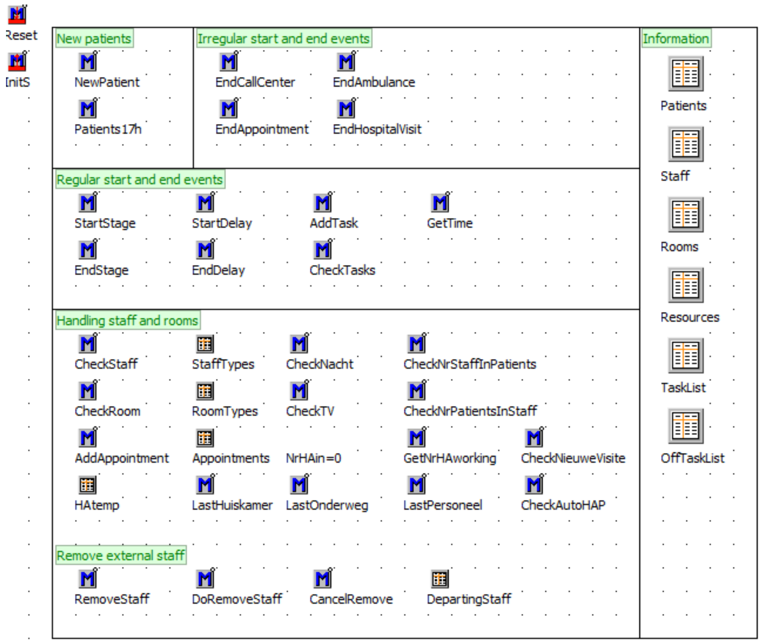


Figure 82: Visualization of the "info" frame. This frame includes all decision logic required for the handling of both patients and resources. Therefore, all operational events are managed via this frame.

The frame's methods and table files are classified into six different categories:

- **New patients:** the methods required for the patient's attribute generation;
- **Regular start and end events:** the methods required for the management of the main processes within the IEP Enschede;
- **Handling staff and rooms:** the methods and table files required for a proper allocation of resources to the patients' treatments;
- **Remove external staff:** the methods and table files required for the removal of external staff members that visited the IEP temporarily.
- **Information:** all table files that store data about the simulation's progress.

P.5.2. Methods

- **Reset:** resets all table files and variables in the "Info" frame;
- **InitS:** initializes all the table files and variables in the "Info" frame.

The section "New patients" includes two methods only for the creation of new MUs:

- **NewPatient:** Register the patient's arrival at the Integrated Emergency Post Enschede and determine the patient's initial attributes, including the logistic care path.
- **NewPatient17h:** register the patient's arrival at the Integrated Emergency Post Enschede and determine the patient's initial attributes, including the logistic care path. This method is executed only once the GP post opens operating. ED activities are randomly created. This method is not used anymore.

The section "Regular start and end events" includes the methods that manage the most important and most frequently applied events. Seven different methods are implemented in order to create, pause or end the activities required within the process:

- **StartStage:** Evaluate if a task could be executed. Therefore, all required resources should be available. The function requires one input variable, the task's activity to be performed. The function returns a boolean, which is TRUE if and only if all resources are available.

- **EndStage:** Manage the tasks' completion, including the allocation of resources and patients;
- **StartDelay:** start the delay action if all resources are allocated properly;
- **EndDelay:** Complete the delay activities initialed, which include all activities without direct interaction with the patient itself.
- **AddTask:** start the delay action if all resources are allocated properly;
- **CheckTasks:** Checks all tasks that are waiting to be performed (see table file “TaskList”). Investigate if all required resources are available for execution. If true, the task is activated and removed from the task list
- **GetTime:** Obtain the processing time required for the patient's next activity. The patient's activity is required as data input. Additional information may be required in order to represent the ED activities, like the usage of a medical specialist and the treatment group. The function exports the expected duration in time format.

The section “Handling staff and rooms” includes all methods required for the proper allocation of resources to the patient’s treatment:

- **CheckStaff:** evaluate if the required staff member is available.
- **CheckRoom:** evaluate if the required room is available.
- **AddAppointment:** invite a GP patient for a physical consult at the GP post;
- **LastHuiskamer:** update some patient characteristics if the patient leaves the waiting room;
- **CheckNacht:** check who is responsible for the triage of self-referrals;
- **CheckTV:** check if a dedicated triage nurse is available;
- **LastOnderweg:** update some patient characteristics once the patient leaves the IEP;
- **CheckNrStaffInPatients:** determine if the number of staff allocations is correctly executed.
- **CheckNrPatientsInStaff:** determine if the number of patient allocations is correctly executed.
- **GetNrHAworking:** determine how many GPs are currently working inside the GP post itself;
- **LastPersoneel:** update some staff characteristics once the patient finishes an activity;
- **CheckNieuweVisite:** determine if a new GP visit at home is required, which prevents the GP post's car to return after finishing another visit.
- **CheckAutoHAP:** evaluate the number of cars available at the moment.

The last section “Remove external staff” is concerned with the deletion of external staff members once their role is fulfilled:

- **RemoveStaff:** plan the removal of external staff members, some waiting time is included;
- **DoRemoveStaff:** actually remove the external staff member from the IEP;
- **CancelRemove:** the staff is requested for a new patient, cancel the removal.

The section “Irregular start and end events” includes four methods which that are initiated once a process is ended.

- **EndCallCenter:**
- **EndAppointment:**
- **EndAmbulance:**
- **EndHospitalVisit:** Remove the patient from the hospital and store its attributes (if required);

P.5.3. Table files

The “Information” section includes all information about the simulation’s progress. These table files are very useful for verification purposes:

- **Patients:** keep track of the patients' characteristics;
- **Staff:** keep track of the staff's characteristics;
- **Rooms:** keep track of the rooms' characteristics;
- **Resources:** keep track of the resources' characteristics;
- **TaskList:** all tasks waiting for resource allocations;
- **OffTaskList:** all tasks performed without direct contacting the patient.

The "Handling staff and rooms" section also includes four table files: 1) HAtemp; 2) StaffTypes; 3) RoomTypes and 4) Appointments. These table files are used to prioritize the resource allocations. Finally, the "Remove external staff" section also includes one table file, "DepartingStaff". This table file is used to store the external staff's departure times temporarily.

P.5.4. Variables

There are no variables included within the "Info" frame.

P.6. The EventController

The simulation model's timing routine is represented by the EventController (Figure 83). This dialog includes both the event list and several interfaces that allow the user to modify the simulation's progress. Please notice that the simulation only makes one simulation run with the initial settings inserted into the "Settings" frame once the simulation is activated via the EventController. Please make use of the simulation activation controls at the mainframe (*Figure 80*)

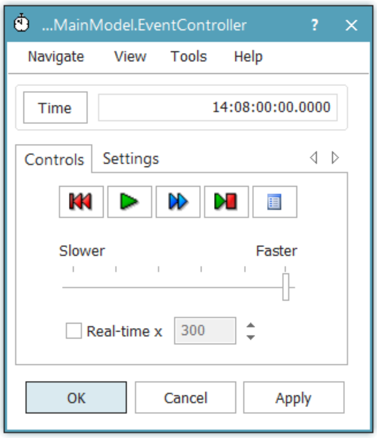


Figure 83: The EventController dialog which allows the user to conduct one experiment only.

P.7. The "Basic" frame

P.7.1. The frame's purposes

The simulation model is mainly build up around the management of critical events. The most important decision logic required to run the simulation model properly are implemented within the "Basic" frame. A visualization of the "Settings" frame is given in Figure 84.

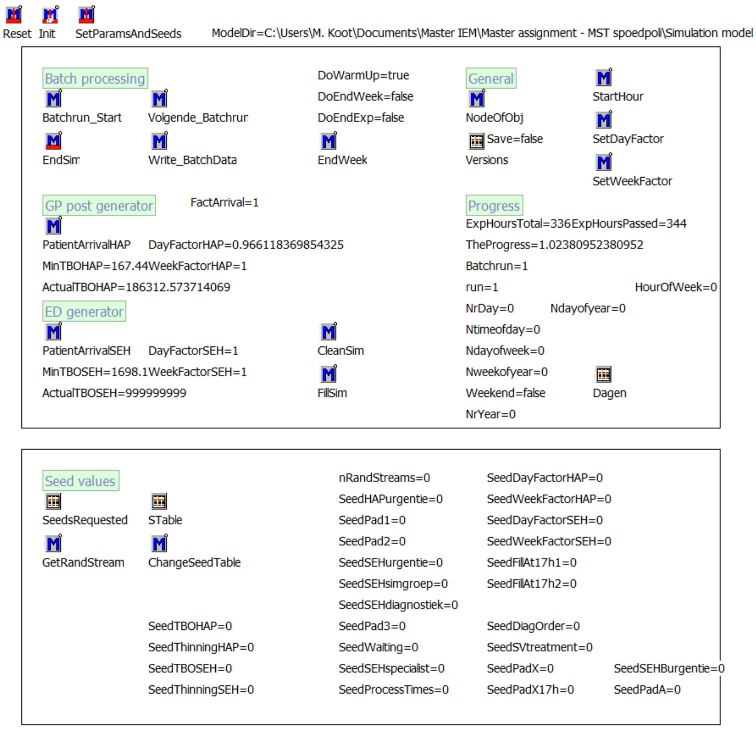


Figure 84: Visualization of the "Basic" frame. This frame is used to manage all events controlling he simulation's progress.

The "Basic" frame includes six categories in which all methods, table files and variables are clustered:

- **Batch processing:** this section includes all methods required for simulating the alternative configurations inserted by the end-user;
- **General:** this section includes all methods required to initiate the hourly events.
- **GP post generator:** this section includes all methods and variables required to generate the arrival of GP post patients properly;
- **ED generator**: this section includes all methods and variables required to generate the arrival of ED patients properly;
- **Progress:** this section includes all variables that keep the end-user informed about the simulation model's progress;
- **Seed values:** this section includes all seed values required for the generation of random numbers within the simulation model.

P.7.2. Methods

The "Basic" frame includes three methods which manage the execution of new experimental configurations. All other methods within the same frame are initiated directly or indirectly by these three methods:

- **Init:** initialize the new simulation run. The data required for the random number generation and the patients' arrival patterns are prepared. The method is initiated by the EventController itself;
- **Reset:** reset the simulation model by restoring the seed values and time counters to their original values, which is equal to zero.
- **SetParamsAndSeeds**: initializes the random seed numbers for each new simulation run. The method is called by the "Init" method on the same frame.

Five methods are included within the "Batch processing" section:

- **Batchrun_Start:** initialize all experiments that the user would like to simulate. The method is only called if the "Start" button is pressed by the user at the "MainModel" frame, which includes the user's interface;
- **Volgende_Batchrun**: this method is used to start the next batchrun. The method communicates with the EventController by initializing, starting and resetting the simulation. The method is either called if the simulation is started by the method "Batchrun_Start" or when an experiment is finished by the method "EndSim";
- **EndSim:** this method keeps control of the experiments to execute, including the replications required for average results. The method is called by the method "Init" at the "Basic" frame, if and only the number of weeks in not used in order to represent one simulation's replications. Therefore, the method determines how long the simulation should running, based on the maximum number of weeks to run;
- **Write_BatchData**: writes the performance data of each replication. The method is called by the "EndSim" method, every time if one experiment is finished;
- **EndWeek**: summarize the weekly performance statistics, if and only if the weeks are used to simulate one replication. The method is called by the method "CleanSim".

Four methods are included within the "General" section:

- **NodeOfObj**: the purpose of this method remains unknown, it is never used.
- **StartHour**: this method updates the time counters and calculates the patient arrival rates per hour, day and week. The resources' availabilities are also updated. The function is first called by the initialization method within the "Basic" frame, after that the method initiates itself every hour. Most input data is gathered from the "Settings" frame;
- **SetDayFactor**: determines the daily factor, based on the probability distribution applicable {Normal; Lognormal; Weibull; Deterministic}. The procedure adapts the day factor in the "Basic" frame for the GP post or ED separately. The method is initiated by the "StartHour" method every hour;
- **SetWeekFactor**: determine the weekly factor, based on the probability distribution applicable {Normal; Lognormal; Weibull; Deterministic}. The procedure adapts the day factor in the "Basic" frame for the GP post or ED separately. The method is initiated by the "StartHour" method every first day of the week.

The GP post patients' arrival processes is initiated by one method only:

- **PatientArrivalHAP**: this method generates all GP post's callers and self-referrals. The inter-arrival time is assumed to be exponentially distributed.

The ED patients' arrival processes is initiated by one method only, two methods are used to fill or clean the simulation during regular operating hours (8:00 am and 5:00 pm during working days):

- **PatientArrivalSEH**: this method generates the arrivals of all ED's external referrals. The inter-arrival time is assumed to be exponentially distributed;
- **CleanSim**: eliminates all MUs, patient events and performances, if and only if the out-of-hours care is simulated only. The method is called by the method "EndSim" if an experiment is fully simulated;
- **FillSim**: fills the simulation model with ED patients if the out-of-hours are simulated only between 5:00pm and 8:00 am during working days. The method is activated via the "StartHour" method.

The random number generation is governed by two method in the section "Seed values":

- **GetRandStream**: this function returns the next available random stream number. The method is called by the "SetParamsAndSeeds" method on the same frame, the resulting stream value is also returned to the "SetParamsAndSeeds" method;
- **ChangeSeedTable**: initializes the seed values table, which contains the seed values of the random number streams. The method is either called at the beginning by the method "Batchrun_Start" or at the end of the simulation by the method "EndSim".

P.7.3. Table files

Four table files are inserted into the "Basic" frame:

- **Versions:** an overview of all models saved, including the saving date, time and name. The table file is stored within the "General" section.
- **Dagen:** list of all days within one week (Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday). Please notice that the days are stored in Dutch only, which explains the Dutch title of this table file. The table file is stored within the "Progress" section.
- **SeedsRequested:** an overview of all methods that requested a seed value once or multiple times. The table's Y dimension is used to generate a new seed value. The table file is stored within "Seed values" section.
- **STable:** an overview of all seed values available. The table file is stored within "Seed values" section.

P.7.4. Variables

The section "BATCH PROCESSING" includes three variables in order to configure the simulation's batch processing configurations:

- **DoWarmUp** {Boolean}: indicates if a warm-up period is simulated;
- **DoEndWeek** {Boolean}: indicates if the method "EndWeek" is used;
- **DoEndExp** {Boolean}: indicates if the method "EndSim1" or "EndSim2" is used.

The section "GP POST GENERATOR" includes four variables used to represent the GP post patients' arrival progresses:

- **MinTBOHAP** {integer}: the minimum time between the GP post patients' arrival intervals;
- **ActualTBOHAP** {integer}: the actual time until the arrival of the next GP post patient;
- **DayFactorHAP** {integer}: the day factor currently applicable to GP post arrivals;
- **WeekFactorHAP** {integer}: the week factor currently applicable to GP post arrivals.

The section "ED generator" includes four variables used to represent the ED patients' arrival progresses:

- **MinTBOSEH** {integer}: the minimum time between the ED patients' arrival intervals;
- **ActualTBOSEH** {integer}: the actual time until the arrival of the next ED patient;
- **DayFactorSEH** {integer}: the day factor currently applicable to ED arrivals;
- **WeekFactorSEH** {integer}: the week factor currently applicable to ED arrivals.

The section "Progress" includes thirteen variables in order to keep the user informed about the simulation's progress:

- **ExpHoursTotal** {integer}: the total hours required to simulate all experiments inserted;
- **ExpHoursPassed** {integer}: the total hours already simulated;
- **TheProgress** {real}: the total hours already simulated divided by the total hours required;
- **Batchrun** {integer}: the number of experiments already simulated;

- **Run** {integer}: the number of replications already simulated;
- **HourOfWeek** {integer}: the hours already simulated in the current week;
- **NrDay** {integer}: the number of days simulated already;
- **Ndayofyear** {integer}: the number of days simulated within the current year;
- **Ntimeofday** {integer}: the hour interval currently simulated;
- **Ndayofweek** {integer}: the day number currently simulated;
- **Nweekofyear** {integer}: the week number currently simulated;
- **Weekend** {Boolean}: a Boolean which represents if it's weekend or not;
- **NrYear** {integer}: the number of year currently simulated.

The section"SEED VALUES" includes 27 seed values used for the generation of random numbers within the simulation model:

- **SeedTBOHAP** {integer}
- **SeedThinningHAP** {integer}
- **SeedTBOSEH** {integer}
- **SeedThinningSEH** {integer}
- **nRandStreams** {integer}
- **SeedHAPurgentie** {integer}
- **SeedPad1** {integer}
- **SeedPad2** {integer}
- **SeedSEHurgentie** {integer}
- **SeedSEHsimgroep**{integer}
- **SeedSEHdiagnostiek** {integer}
- **SeedPad3** {integer}
- **SeedWaiting** {integer}
- **SeedSEHspecialist** {integer}
- **SeedProcessTimes** {integer}
- **SeedDayFactorHAP** {integer}
- **SeedWeekFactorHAP** {integer}
- **SeedDayFactorSEH** {integer}
- **SeedWeekFactorSEH**
- **SeedFillAt17h1** {integer}
- **SeedFillAt17h2** {integer}
- **SeedDiagOrder** {integer}
- **SeedSVtreatment** {integer}
- **SeedPadX** {integer}
- **SeedPadX17h** {integer}
- **SeedSEHBurgentie** {integer}
- **SeedPadA** {integer}

P.8. The “Settings” frame

P.8.1. The frame’s purposes

The settings frame is mainly used to insert all parameter values. All the patient arrivals rates, resource availabilities and logistic care paths are inserted into this frame for both the GP post and ED. A visualization of the “Settings” frame is given in Figure 85.

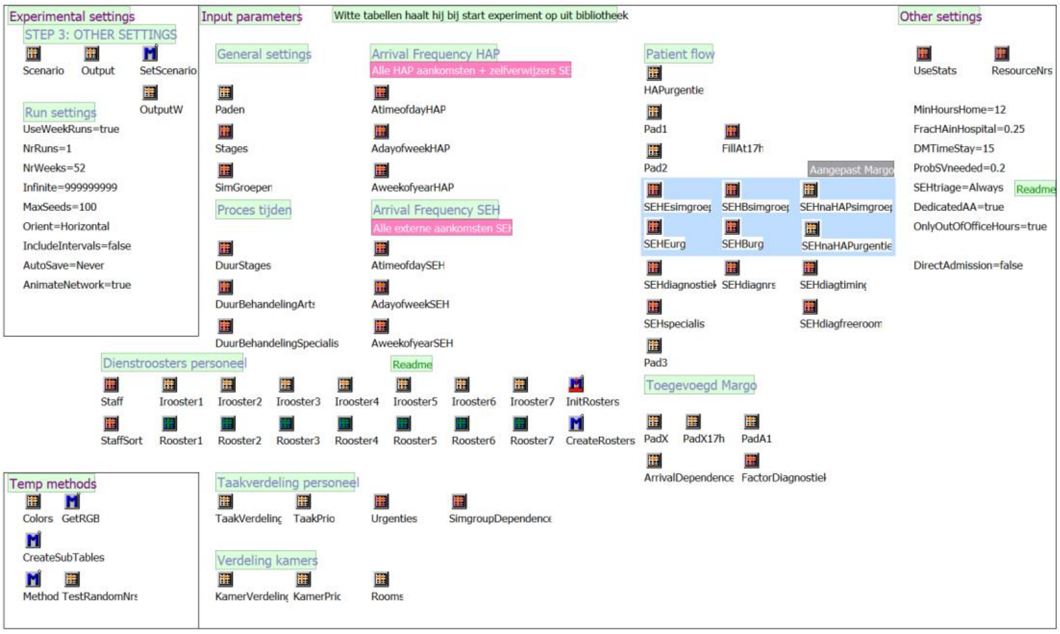


Figure 85: Visualization of the "Settings" frame. This frame is mainly used to insert all input parameters like patient arrival rates, resource availabilities and logistic care paths.

The “Settings” frame includes several categories in which all methods, table files and variables are clustered:

- **Experimental settings:** this section includes all methods, table files and variables required for the definition of the experiments to simulate;
- **General settings:** this section includes the data input required to describe the patients’ logistic care paths, including the alternative activities and patient classifications;
- **Processing times:** this section includes the information required to estimate the duration of each activity. The durations are based on either an empirical or theoretical probability distribution;
- **Arrival frequencies GP post:** this section includes three table files including all data corresponding to the arrival of GP post patients;
- **Arrival frequencies ED:** this section includes three table files including all data corresponding to the arrival of ED patients;
- **Patient flows:** this section includes all table files in order to allocate each patient into the correct logistic care path;
- **Staff rosters:** this section includes a description of all staff positions available. A staff roster is made for each day of the week;
- **Staff task allocations:** this section includes several prioritization schemes used for resource allocations;

- **Room distributions:** this section includes all data regarding the rooms' availabilities, priorities and patient usage.
- **IEP adjustments:** this section includes all method adjustments implemented by Koster (2014). These adjustments were required in order to customize the model to the IEP organization in Enschede;
- **Temp methods:** this section includes temporary methods for testing only;
- **Other settings:** this section includes all other variables and table files required in order to make sure all patients are correctly simulated.

P.8.2. Methods

Two main methods are inserted into this frame: 1) InitRosters and 2) CreateRosters. These methods are used for the generation of the rosters corresponding to the experiment's staff allocations.

- **InitRosters: t**his method initializes the staff rosters for both the GP post and the ED, based on the staff members' arrival and departure patterns inserted per hour interval of each day. The method mainly initializes the rosters' layouts and calculates the minimum number of employees hired for each staff position. The method is called by the method "Init" once a new experiment is simulated;
- **CreateRosters:** this method creates the rosters for both the GP post and the ED, based on the initial arrival and departure schedules inserted. A feasibility check is implemented within the method. If the time between two consecutive shifts is less than required for one employee, than the number of employees for the corresponding staff position is increased and a new roster is created. The method is called by the method "InitRosters" repeatedly, until a feasible schedule is found.

Finally, the section "Temp methods" also includes three methods: 1) "GetRGB"; 2) "CreateSubTables" and 3) "Method". However, these methods were only used for testing purposes only and could be eliminated without any disturbances.

P.8.3. Table files

Several input parameters are required in order to simulate the IEP's processes properly. Most of these parameters are inserted into table files within the "Settings" frame. The table files are clustered into several categories, based on the type of information represented by the input parameters. The table files included within the "Settings" frame are elaborated per cluster.

- **Scenario**: includes all experiment scenarios to be simulated, including the factors' values;
- **Output:** represents which data is stored in which table file in the "Performance" frame;
- **OutputW:** represents which data is stored in which table file in the "Performance" frame.

Three table files are inserted to represent the simulation's general settings. All three table files include static information, which remain unchanged once the simulation started:

- **Paden:** represents all logistic care paths available for a patient;
- **Stages:** represents all activities that a staff member can execute;
- **SimGroepen:** represents the classification structures applied to all ED patients.

Three table files are inserted to represent the GP post's patient arrivals:

- **AtimeofdayHAP**: represents the average number of daily GP post patient arrivals per hour;
- **AdayofweekHAP**: represent the distribution of the weekly GP post patient arrivals;

- **AweekofyearHAP**: represents the distribution of the yearly GP post patient arrivals.

The arrival rates include all patients that contacted the GP post in order to gain access for emergency care. The arrival rates also include the total number of out-of-hours self-referrals contacting the ED, because these patients should be examined by the GP post first. All three table files include static information, which remain unchanged once the simulation started. Different values can be inserted to simulate another patient arrival scenario.

Three table files are inserted to represent the ED's patient arrivals:

- **AtimeofdaySEH**: represents the average number of daily ED patient arrivals per hour;
- **AdayofweekSEH**: represent the distribution of the weekly ED patient arrivals;
- **AweekofyearSEH**: represents the distribution of the yearly ED patient arrivals.

The arrival rates include all patients that are referred to the ED in order to gain access for emergency care. Self-referrals are only included during workdays between 8:00 am and 5:00 pm, because the GP post is closed within these time intervals. All three table files include static information, which remain unchanged once the simulation started. Different values can be inserted to simulate another patient arrival scenario.

The patients' logistic care paths were already explained within the table file "Paden" in the section "General settings". However, more information is required in order to simulate the patient's care paths properly. First of all, the patient's urgency classification should be determined. The relevant care path is strongly dependent on the patient's urgency classification, for example, a high urgency case would probably go to the ED immediately without visiting a GP consult first. Secondly, the ratio of care paths used should be determined for each urgency classification available. These ratios are should be determined for the GP post and ED separately:

- **HAPurgentie:** distribution of all GP post's urgency classification allocated per hour;
- **Pad1:** distribution of the care paths through the GP post allocated per urgency classification;
- **Pad2:** distribution of the care paths allocated after conducting a consult within the GP post;
- **Pad3:** distribution of the care paths through the ED allocated per urgency classification.
- **SEHEsimgroep:** distribution of all ED's specialist classification allocated to the external ED patients per hour;
- **SEHEURG:** distribution of the ED's urgency classifications allocated to the external ED patients per specialist group;
- **SEHBsimgroep:** distribution of all ED's specialist classification allocated to the self-referrals arriving at the ED per hour;
- **SEHBurg:** distribution of the ED's urgency classifications allocated to the self-referrals arriving at the ED specialist group;
- **SEHnaHAPsimgroep:** distribution of all ED's specialist classification allocated to the ED patients referred by the GP post per hour;
- **SEHnaHAPurgentie:** distribution of the ED's urgency classifications allocated to the ED patients referred by the GP post per specialist group;
- **SEHdiagnostiek:** represents the probability that a certain diagnostic test is required for each type of patient group available;
- **SEHdiagnrs:** the number of test required for each type of patient group, if and only if the patient should undergo these test at all;

- **SEHspecialist:** represents the probability that a medical specialist is required for the treatment of an ED patient. The waiting time for arrival of the medical specialist is also included;
- **SEHdiagtiming:** table file including Boolean values only, representing if the diagnostic test should be planned carefully or not;
- **SEHdiagfreeroom:** indicates if the diagnostic test is performed outside the ED.

The table file **"FillAt17h"** is used to fill the ED with patients within the simulation model after 5:00 pm every day. Previous research was only interested into the effects of integrating the out-of-hours care. Therefore, the ED operations between 8:00 am and 5:00 pm (workdays only) were not required to simulate. A Weibull distribution was used to implement a proper number of patients into the ED after 5:00 pm, the start event of the out-of-hours emergency care.

Three table files are inserted to represent the activities' processing times:

- **Duurstages:** represents all activities' duration distributions and corresponding parameters;
- **DuurBehandelingArts:** represents the ED residents' treatment durations per patient group.
- **DuurBehandelingSpecialist:** represents the medical specialists' treatment durations per patient group within the ED.

All three table files include static information, which remain unchanged once the simulation started. Different values can be inserted to simulate another organizational scenario.

Four different types of table files are inserted in order to upload the staff rosters within the simulation model:

- **Staff:** represents the type and number of staff members available within the simulation.
- **Irooster:** intial rosters representing the number of staff member arrivals and/or departures per hour interval. An initial roster is made for each day of the week;
- **Rooster:** Boolean roster which represents the availability of all staff members per hour interval. A roster is made for each day of the week;
- **Staffsort:** auxiliary table file used for the initialization of the rosters.

The "Staff" and "Irooster" table files include static information, which remain unchanged once the simulation started. The type and number of available staff positions can be altered in order to simulate another organizational scenario. The "Rooster" table files are dependent on the values inserted in the "Staff" and "Irooster" table files.

Four table files are included in order to make sure the activities are performed by the correct type of staff members:

- **TaakVerdeling:** an overview of which activities each staff member can perform;
- **TaakPrio:** an overview which staff member is prioritized to perform each activity first;
- **Urgentie:** an overview of the urgency levels applicable within the GP post and ED, including the maximum waiting times allowed for each urgency classification;
- **SimgroupDependence:** represents which resident is responsible for which patient type.

All four table files include static information, which remain unchanged once the simulation started. Different values can be inserted to simulate another organizational scenario.

P.8.4. Variables

Within the section “Run settings”, eight different variables are included in order to represent the simulation’s progress:

- **UseWeekRuns** {Boolean}: indicates if one replication is represented by one week simulated;
- **NrRuns** {integer}: the cumulative number of simulation experiments executed;
- **Infinite** {integer}: the largest value used within the simulation model;
- **MaxSeeds** {integer}: the largest number of seed values allowed within the simulation model;
- **Orient** {string}: indicates the format used within the “Performance” frame’s results;
- **IncludeIntervals** {Boolean}:
- **AutoSave** {string}: indicates if the model should be saved automatically after completion.
- **AnimateNetwork** {Boolean}: the function of this variable remains unknown.

The section “Other settings” includes all other variables required:

- **MinHoursHome** {integer}: the minimum hours required between two working shifts;
- **FracHAinHospital** {real}: the fraction of time that a GP is present within the hospital;
- **DMTimeStay** {integer}: the time that a diagnostic employee stays at the IEP unutilized;
- **ProbSVneeded** {real}: probability that a ED nurse is required during the patient’s treatment;
- **SEHtriage** {string}: 4 different triage alternatives available {Always, Extern, Never, Integrated}
- **DedicatedAA** {Boolean}: indicates if the assistants/nurses are dedicated to multiple patients;
- **OnlyOutOfOfficeHours** {Boolean}: indicates if the out-of-hours are simulated only;
- **DirectAdmission** {Boolean}: indicates if an ED patient has to wait for hospital admission.

P.9. The “Performance” frame

P.9.1. The frame’s purposes

The “Performance” frame is mainly used provide all the simulation’s results to the end-user. All the experiments’ KPIs are stored within this frame, including some confidence interval calculations. A visualization of the “Performance” frame is given in Figure 86.

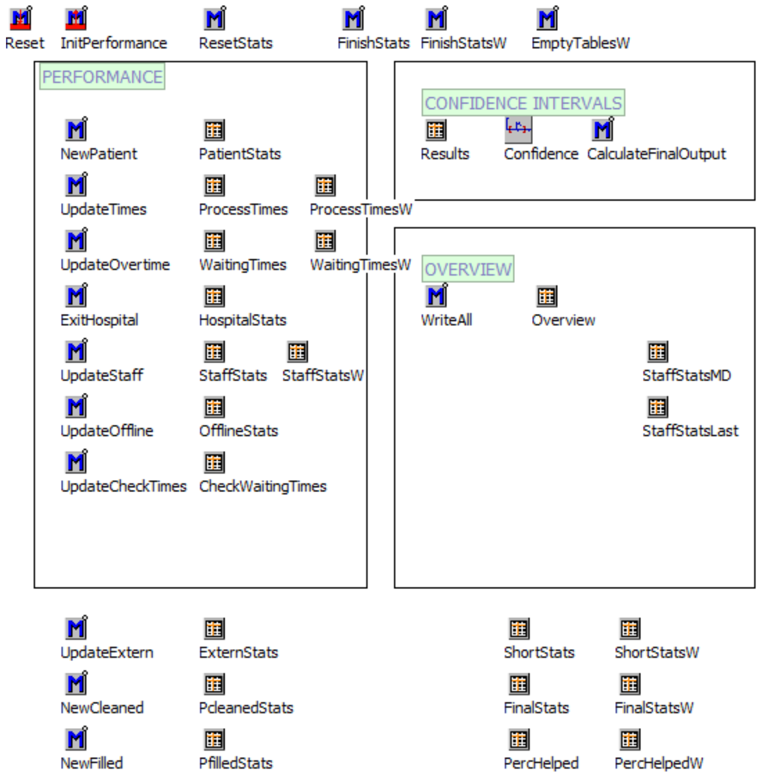


Figure 86: Visualization of the "Performance" frame. This frame is mainly used to visualize all the simulation's results gathered during experimentation.

The "Performance" frame includes several categories in which all methods, table files and variables are clustered:

- **Performances per KPI:** this section includes all methods used to gather the simulation model's progress into predefined table files.
- **Confidence intervals:** determine the confidence intervals of all scenarios simulated.
- **Overview:** gather the simulation experiments' results into one simple overview.

P.9.2. Methods

The "Performance" frame includes methods for the storage of data only. All methods are focused to gather the simulation model's progress into predefined table files. The following methods are included into the "Performance frame without any further classification.

- **Reset:** delete all performance data gathered. The method is called by the EventController;
- **InitPerformance:** initializes all table files required for the performance registration;
- **ResetStats:** Reset and initialize all performance data gathered after one day. This method is mainly used to link the "InitPerformance" and "Reset" method in the same frame;
- **FinishStats:** reset and initialize all performance measurements, store the values into the table file "FinalStats";
- **FinishStatsW:** reset and initialize all performance measurements per week;
- **EmptyTablesW:** reset performances per week by emptying the corresponding table files;
- **UpdateExtern:** store the information of all external activities executed;
- **NewCleaned:** store the patients' characteristics before cleaning up the system;

- **NewFilled:** this model is outdated. It's original purpose was to store the patient's characteristics once a new out-of-hours emergency care is initiated.

Most methods are stored within the "Performances per KPI" section. This section includes all decision logic required to store the KPIs separately into predefined table files. The methods' names are quite straightforward:

- **NewPatient:** register all characteristics of each newly arriving patient;
- **UpdateTimes:** store the patient's processing and waiting times for each activity;
- **UpdateOvertime:** store the cumulative overtime for each staff position separately;
- **ExitHospital:** store the patient's attributes once the patient leaves the hospital;
- **UpdateStaff:** store the staff members' time statistics;
- **UpdateOffline:** Store the staff's offline task allocation.
- **UpdateCheckTimes:** Store the processing times of the check activity scheduled.

The section "Confidence intervals" includes one method only, "**CalculateFinalOutput".** This method calculates the scenarios' final results, including the 95% confidence intervals. The results are copied into the "Results

The section "Overview also includes one method only, "**WriteAll**". This method stores the experiments' data into the "Overview" table file, which is an extended version of the "Scenario" table file of the "Settings" frame. This file is useful for exporting the data into other software packages.

P.9.3. Table files

The "Performances per KPI" section includes the most table files, which are required to store the simulation model's output variable per KPI category. The same type of announcements are used as the methods implemented within the same section:

- **PatientStats:** Store the patient's characteristics (arrival time, logistic care paths taken, urgency levels, staff allocations and length of stay per organization);
- **ProcessTimes:** Store the processing times of all patients per activity;
- **ProcessTimesW:** the same data is stored weekly as for the "ProcessTimes" table file;
- **WaitingTimes:** Store all waiting times of all patients in front of each activity;
- **WaitingTimesW:** the same data is stored weekly as for the "WaitingTimes" table file;
- **HospitalStats:** Store the number of exit types allocated to all patients that contacted the IEP;
- **StaffStats:** Store the staff movements events in order to calculate KPIs like regular working time, overwork time and utilization rates;
- **StaffStatsW:** the same data is stored weekly as for the "StaffStats" table file;
- **OfflineStats:** Store the offline activity durations;
- **CheckWaitingTimes:** additional table file used for verification purposes.

The confidence intervals section includes one table file only, the "Results" table file. This table file stores all the aggregated information about the experiments' results. The 95% confidence intervals are automatically calculated for all KPIs.

The section "Overview" stores all the aggregated results per experiment. This will enable the end user to gain an overview of the experiments' results. The "Overview" table file is used for this purpose, while the "StaffStatsMD" and "StaffStats.ast" table files are used for the storage of staff related data.

Finally, some table files are stored within the “Performance” frame without any further classification:

- **ExternStats:** performance data regarding the external employees requested by the IEP;
- **PcleanedStats:** overview of the number of patients removed by the model;
- **PfilledStats:** overview of the number of patients created instantly by the model;
- **ShortStats:** patients’ characteristics summary;
- **ShortStatsW:** patients’ characteristics summary per week;
- **FinalStats:** an overview of the most important KPIs gathered during the simulation;
- **FinalStatsW:** an overview of the most important KPIs gathered per week simulated;
- **PercHelped:** fraction of the patients helped by the GP post or ED successfully;
- **PercHelpedW:** fraction of the patients helped successfully per week.

P.9.4. Variables
There are no global variables included within the “Performance” frame.

P.10. The “Experiments” frame

P.10.1. The frame’s purposes
The “Experiments” frame is used to implement the decision logic required in order to conduct several experiments automatically. Please notice that the scenarios itself are formulated in the “Settings” frame (Figure 87).

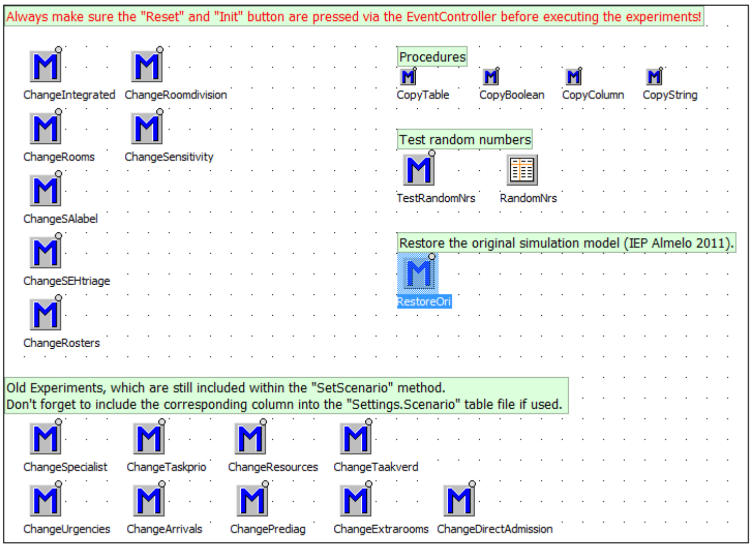


Figure 87: Visualization of the “Experiments" frame. This frame is mainly used to implement the decision logic required for experimentation purposes. The configurations itself are prepared in the “Settings” frame.

Koster (2014) defined several alternative interventions which the used can select:

1. Expanding the ED doctor’s authorities;
2. Increase the amount of staff at the GP post:
   a. Add one additional triage nurse to the GP post every hour;
   b. Add one nurse practitioner to the GP post every hour;
   c. Add one general practitioner to the GP post every hour;
3. Use the same triage system by both the GP post and the ED;
4. The GP post and ED can make use of each other’s rooms.

Once the experiments' configurations are made in the "Settings" frame, the methods in the "Experiments" frame communicate with the "SettingsAlt" frame in order to change the simulation's input models. The methods in the "Experiments" frame will copy the data in the "SettingsAlt" frame into the table files of the "Settings" frame. The "SettingsAlt" frame is visualized in Figure 88.

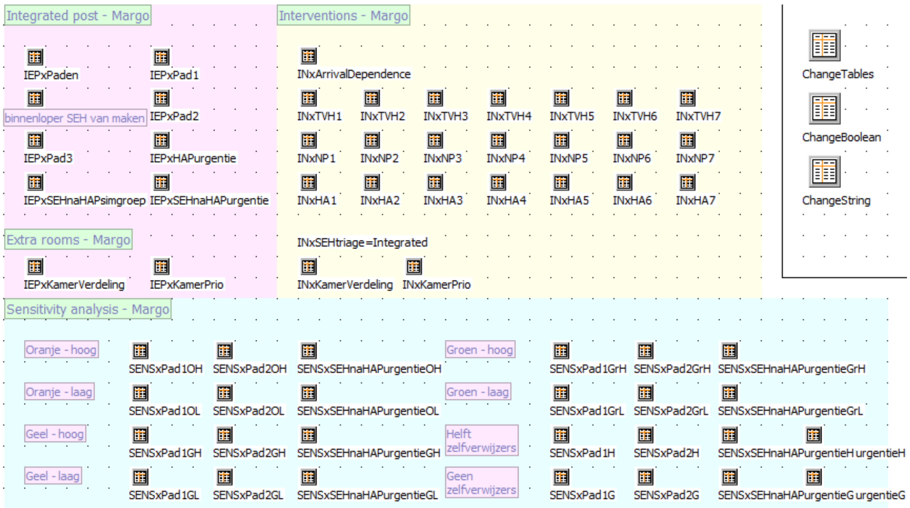


Figure 88: Visualization of the "SettingsAlt" frame, which includes the alternative table files required for experimentations. The frame only includes the same type of table files as implemented in the "Settings" frame, only the data input is changed.

P.10.2. Methods

This frame is mainly build up by methods in order to implement the decision logic required:

- **ChangeIntegrated:** update the logistic care path to the out-of-hours emergency care organization selected;
- **ChangeRooms:** update the room allocations;
- **ChangeSAlabel:** change the type of ED arrivals (labeled and unlabeled);
- **ChangeSEHtriage:** update the requirements of ED triage activities;
- **ChangeRosters:** update the staff members present within the GP post (not the ED);
- **ChangeRoomdivision:** Allow the GP post and the ED to make use of each other's rooms;
- **ChangeSensitivity:** change the urgency levels' frequencies for the sensitivity analysis.
- **CopyTable:** copy the experiment's configurations into from the "SettingsAlt" frame into the "Settings" frame;
- **CopyBoolean:** change the boolean values of the variables inserted;
- **CopyColumn:** update the staff rosters' columns;
- **CopyString:** update the string values given by the scenario;
- **TestRandomNrs:** evaluates the correctness of the random number generation;
- **RestoreOri:** restore the simulation model's initial data input given in the "Settings" frame.

There are also methods included of previous simulation studies. These methods shall not be discussed within this appendix.

P.10.3. Table files

Only one table file is used for the evaluation of the random number creation procedure.

P.10.4. Variables

There are no variables included within the "Experiments" frame.

Appendix Q – Simulation model modifications

The most important modifications made in the simulation model are limited to four frames only: 1) the "Settings" frame; 2) the "Info" frame; 3) the "Basic" frame and 4) the "Experiments" frame. The modifications made in each frame will be discusses separately in the following sections.

Q.1. Settings frame implementations

The *"Settings"* frame is used to implement all the simulation model's input variables required. The conclusions made in chapter 5 *"Data analytics & simulation input"* are therefore implemented into the *"Settings"* frame. However, in order to run the new model properly, additional information is required. Therefore, eleven new table files are implemented:

- The "DayCluster" table file classifies the arrival days into the corresponding arrival set, while the GP post opening hours are stored within the table file "OpeningHoursGPpost". These table files are required for a proper modeling of the patient arrival processes;
- The "ConsultGP" table file includes the probability that either the GP, the GP assistant or the NP is allocated to the physical consult of a GP post patient. The probabilities are updated every hour by the method "StartHour" in the "Settings" frame, while the patient allocation itself is governed by the "CheckStaff" method in the "Info" frame;
- The table file "PathX" includes the distribution of the ED patient arrival, including external and self-referrals only. The GP post referrals are not included;
- The proportion of labeled and unlabeled patients is determined based on the frequencies given in the table files "LabeledExternal" and "LabeledGP" for the external and GP post referrals respectively. The self-referrals are automatically classified as unlabeled patients;
- It is possible for an emergency physician to transfer responsibility of unlabeled patients to another resident once the anamnesis is completed. The "UnlabeledProbability" table file includes these probabilities for each treatment group;
- The probability that a patient requires plaster is determined by the frequencies included within the "PlasterProbability" table file. These probabilities differ for each treatment group and urgency classification;
- It is assumed that the travel duration's distribution is the same for all treatment groups, but that the average length differs. The "DiagWaiting" table file includes the factor corresponding to the travel time required for each diagnostic employee;
- If a resident is called to the ED from an external department, additional travel time is required. These travel times are stored within the "ResidentTravel" table file;
- The "NightTriageED" table file keeps track who is responsible for the triage of self-referrals.

Q.2. Info frame implementations

The *"Info"* frame includes all the essential information about the simulation's progress. This frame also includes the key decision logic required in order to describe the IEP's processes. Several new methods are implemented in order to simulate the new conceptual model properly:

- The GP appointment strategy is changed, in which the both calling patients and self-referrals are allocated to time slots of 10 minutes. One patient may be allocated to a time slot per two residents available. For example, if four GPs are scheduled within a given hour interval, two patients may be invited each ten minutes. It is only allowed to add one high urgent patient (U1) extra into the time slot. A deterministic travel time of 15 minutes is taken into consideration for all calling patients, self-referrals may be referred into the first available time slot. Three methods and one table file are inserted in order to program the new appointment strategy:

    - The “InitAppointments” method is implemented in order to initialize the daily appointment schedule. The time slot interval’s length can be altered by the “ConsultDurationGP” variable within the “Settings” frame;
    - The decision logic is implemented in the method “MakeAppointment”;
    - The method “UpdateAppointments” updates the appointment schedule made once the patient arrives physically at the GP post;
    - The time slot allocations are visualized in the “AppointmentsGP” table file. Separate table files are implemented for the NP and GP’s assistant’s consults.
- The GP post cars availability is determined by the number of GPs present at the GP post itself. The required decision logic is implemented into a new method “AvailabilityCarGP”, which is called every hour;
- The method “FindGPvisit” is implemented in order to evaluate if there exists a patient that waits for a GP visit at home. This method assures that the GP can drive to the patient immediately without returning to the GP post first. The “FindGPvisit” is only called once another GP visit is completed via the method “EndStage”;
- Unlabeled patients that arrive at the ED by ambulance, trauma helicopter or police are placed into an available treatment room immediately for triage, these patients do not have to visit the dedicated triage room in front of the IEP Enschede. Therefore, the method “StartStage” required slight modifications, including several if statements;
- An ED residents can be called to the ED from an external department if no other resident of the type required is physically available. The method *“AvailabilityResident”* makes sure that the staff member leaves the ED again after 30 minutes of idle time;

Most decision logic is implemented within the methods corresponding to the creation of new patients, start- and end events. Therefore, several modifications were required in the methods “NewPatient”, “StartStage”, “EndStage”, “StartDelay” and “EndDelay”. These modifications included table or method references only, a new method was created for more complicated decision logic

Q.3. Basic frame implementations

The “Basic” frame includes the general decision logic required for the creation of discrete events like patient arrivals, staff departures and reactivating the simulation model’s experiments. Most decision logic within the “StartHour” method is altered to updates the time counters, resource availabilities patient arrival rates per hour, day and week. Three new methods are implemented:

- The “FrequenciesConsultGP” method is called every hour in order to evaluate the availability of GP post staff members. If the staff member is available, he/she can be allocated to a physical consult within the GP post;
- If the GP post closes, the remaining patients should be eliminated from the simulation model properly, otherwise the time counters would include too high values. This check is implemented into the “CheckOpenGP” method;
- The method “CheckConsultGP” evaluates if the staff allocations for the physical GP consult should be changed. The NP and GP assistant are not always present at the IEP Enschede. If one of these staff members is absent, all patients waiting for a NP or GPA consult are reallocated to a regular GP.

Appendix R – Model verification

A comparison is made between the input variables inserted into the simulation model and the actual inputs gained once the simulation model completed a full replication consisting of two operational years. This comparison is required in order to verify if the conceptual model is correctly translated into the simulation model. If the actual and simulated input values do not differ significantly, it can be concluded that a proper representation is given of the independent variables, enabling to make comparisons in between the actual and simulated output variables.

The comparison of input variables is applied to the newly developed simulation model only, the model developed by Koster (2014) was already verified. Both the separated (2014-2015) and the integrated (2016-2017) emergency care organizations in Enschede are evaluated. Five different types of input variables are evaluated:

1. The number and type of patient arrivals;
2. The care path allocations;
3. The urgency classifications selected;
4. The ED treatment groups allocated;
5. The processing times of all activities.

The processing times are evaluated by two parameters only: 1) the mean and 2) variance. For all other input variables, the absolute frequencies resulting from the patient records and the simulation model are compared. However, due to small fluctuations in the total number of patients simulated, the relative frequencies are also calculated for the actual and simulated input variables separately.

R.1. Separated emergency care (2014-2015)

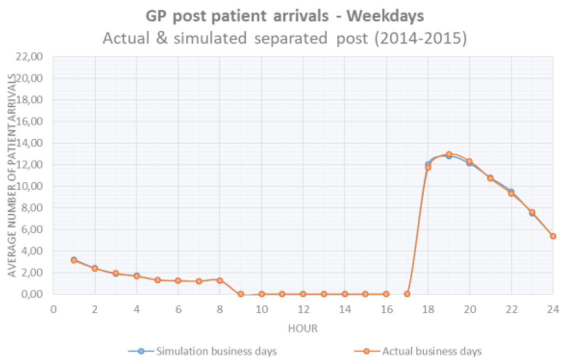
R.1.1. Patient arrivals

The total number of patient arrivals should be examined first (Table 67). It can be concluded that no large differences are found in between the actual and simulated number of patient arrivals. The number of simulated self-referrals is slightly less in comparison with the actual number of patient referrals (-3%). The number of ED patients simulated in slightly larger than the actual number of patients visiting the ED, which is mainly explained by the exclusion of holidays from the data analysis.

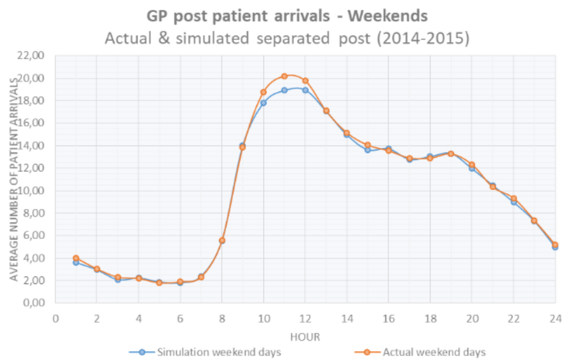
Organization (2014-2015)	Arrival type	ED Label	Absolute frequencies			Relative frequencies		
			Records	Simulation	Difference	Records	Simulation	Difference
GP post	self-referrals	-	2223	2161	-3%	0,024	0,023	0%
	caller	-	89316	90030	1%	0,976	0,977	0%
ED	self-referral	Labeled	-	-	-	-	-	
	self-referral	Unlabeled	10403	10558	1%	0,194	0,193	0%
	external referral	Labeled	19026	19458	2%	0,355	0,356	0%
	external referral	Unlabeled	12074	12407	3%	0,225	0,227	0%
	GP post referral	Labeled	8947	9045	1%	0,167	0,165	0%
	GP post referral	Unlabeled	3188	3203	0%	0,059	0,059	0%

Table 67: Verification of the patient arrivals within the IEP Enschede (2014-2015).

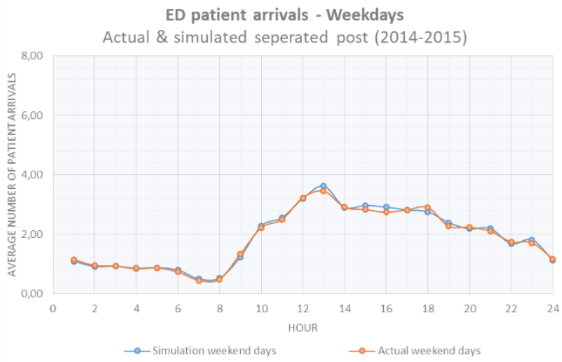
The simulation model's patient arrival rates are determined for each hour separately. The weekdays and the weekends included different arrival patterns, therefore the arrival rates are determined for these two sets separately. No significant differences could be found between the actual and simulated hourly arrival rates for both the GP post and the ED (Figure 89).



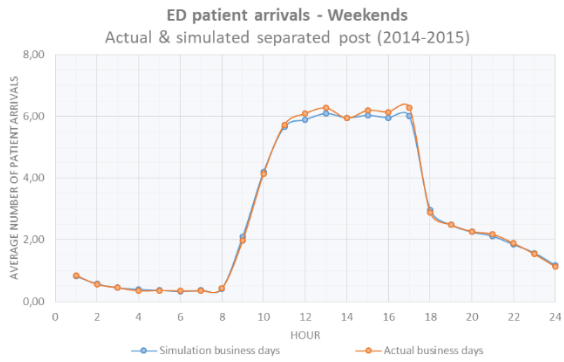
a) GP post weekday arrivals (from Monday until Friday)



b) GP post weekend arrivals (Saturday and Sundays)



c) ED weekday arrivals (from Monday until Friday)



d) ED weekend arrivals (Saturday and Sundays)

Figure 89: Comparison of the actual and simulated hourly patient arrivals, visualized by the blue and red graphs respectively.

R.1.2. Care pathways

The absolute and relative allocations of both the separated GP post and the ED care pathways are visualized in Table 68. The allocation of the ED's care pathways seem not to differ significantly, only small differences of approximately +/- 5% are found for the care pathways with a relative small number of patient allocations. For example, the number of A2 patients simulated are 6% less in comparison with the actual number of these patients obtained from the patient records. However, the absolute difference of -13 patients is acceptable in comparison with the 91539 GP post patients.

A-path integrated (2014-2015)		Absolute frequencies			Relative frequencies		
		Records	Simulation	Difference	Records	Simulation	Difference
A1	IEP self-referral - physical triage - ED consult	-	-	-	-	-	-
A2	IEP self-referral - physical triage - home	228	215	-6%	0,002	0,002	0%
A3	IEP self-referral - physical triage - GP post consult	1995	1946	-2%	0,022	0,021	0%
A4	Caller - telephonic triage - home	31078	31133	0%	0,340	0,338	0%
A5	Caller - telephonic triage - ED consult	1382	1409	2%	0,015	0,015	0%
A6	Caller - telephonic triage - GP visit - home	8663	8774	1%	0,095	0,095	0%
A7	Caller - telephonic triage - GP visit - ED consult	470	447	-5%	0,005	0,005	0%
A8	Caller - telephonic triage - GP consult	40023	40532	1%	0,437	0,440	0%
A9	Caller - telephonic triage – tel. consult - home	7700	7735	0%	0,084	0,084	0%
B1	GP post consult - home	30974	31326	1%	0,737	0,737	0%
B2	GP post consult - X-ray - home	761	760	0%	0,018	0,018	0%
B3	GP post consult - X-ray - ED consult	789	828	5%	0,019	0,019	0%
B4	GP post consult - ED consult	9494	9564	1%	0,226	0,225	0%
C1	ED consult – home	29148	29721	2%	0,543	0,544	0%
C2	ED consult – hospital admission	24490	24950	2%	0,457	0,456	0%
X1	ED external referral - ED consult	31100	31865	2%	0,749	0,751	0%
X2	ED self-referral - ED consult	10403	10558	1%	0,251	0,249	0%

X3	GP post referral - ED consult	12135	12248	1%	0,292	0,289	0%

Table 68: Verification of the care pathway allocations made within the IEP Enschede (2014-2015).

R.1.3. Urgency classifications

The GP post's and ED's urgency classifications for the separated emergency care in Enschede are visualized in *Table 30*. The GP post's simulated urgency classifications are not significantly different from the actual urgency classifications. The ED's urgency classifications assigned within the actual and simulated system are also approximately equal to each other.

Urgency classification (2014-2015)		Absolute frequencies			Relative frequencies		
		Records	Simulation	Difference	Records	Simulation	Difference
GP post	U0	-	-	-	-	-	-
	U1	1545	1588	3%	0,017	0,017	0%
	U2	11822	12034	2%	0,129	0,131	0%
	U3	35706	35806	0%	0,390	0,388	0%
	U4	17504	17562	0%	0,191	0,190	0%
	U5	24944	25201	1%	0,273	0,273	0%
ED	U0	886	892	1%	0,017	0,016	0%
	U1	7995	8253	3%	0,149	0,151	0%
	U2	27083	27527	2%	0,505	0,504	0%
	U3	17475	17775	2%	0,326	0,326	0%
	U4	160	155	-3%	0,003	0,003	0%
	U5	-	-	-	-	-	-

Table 69: Verification of the urgency classifications assigned within the IEP Enschede (2014-2015).

R.1.4. ED treatment groups

The ED treatment group allocations are visualized in Table 70, no significant differences can be found in between the actual and simulated number of treatment group allocations. All absolute frequencies simulated differ no more that 4% in comparison with the actual number of patients allocated.

ID	Treatment group (2014-2015)	Absolute frequencies			Relative frequencies		
		Records	Simulation		Records	Simulation	Difference
S1	Surgery	28830	29406	2%	0,537	0,538	0%
S2	Internal medicine	5713	5833	2%	0,107	0,107	0%
S3	Neurology	3880	3901	1%	0,072	0,071	0%
S4	Orthopedics	5199	5217	0%	0,097	0,095	0%
S5	Pulmonary medicine	4549	4680	3%	0,085	0,086	0%
S6	Gastrointestinal & liver	2907	3032	4%	0,054	0,055	0%
S7	Other	2560	2602	2%	0,048	0,048	0%

Table 70: Verification of the patient arrivals within the IEP Enschede (2014-2015).

R.1.5. Processing times

The durations of all activities simulated are stored within a separate table file, which makes it possible to generate the mean and variance for all durations (Table 71). No significant differences can be found for almost all activities. The duration of some activities are slightly underestimated by the simulation model, which is mainly explained by the elimination of the patient record's outliers.

Organization	activity	Actual durations		Simulated durations		Difference	
		Mean	Stdev	Mean	Stdev		
GP post	Telephonic triage					2%	4%
	Physical triage					-6%	-1%
	GP physical consult					-1%	-4%
	GP visit					0%	-2%
	GP driving duration					0%	-1%
	GP telephonic consult					0%	0%
	NP consult					0%	-2%
	GP assistant consult		CONFIDENTIAL			-	-
ED	Physical triage					0%	2%
	CT scan waiting					0%	4%
	CT scan duration					-3%	6%
	Ultrasound waiting					-4%	-1%
	Ultrasound duration					0%	4%
	X-ray waiting					-2%	1%
	X-ray duration					-2%	4%

Table 71: Comparison between the mean and standard deviation of all actual and simulated activities' durations (2014-2015).

R.2. Integrated emergency care (2016-2017)

R.2.1. Patient arrivals

The total number of patient arrivals should be examined first (Table 72). It can be concluded that no large differences are found in between the actual and simulated number of patient arrivals. The number of patients simulated never differs more than +/- 5% in comparison with the actual number of patients for all arrival types. The number of simulated self-referrals is slightly less in comparison with the actual number of patient referrals (-3%) for both the GP post and the ED. However, the relative frequencies of the GP post and the ED are the same for both the actual and simulated system.

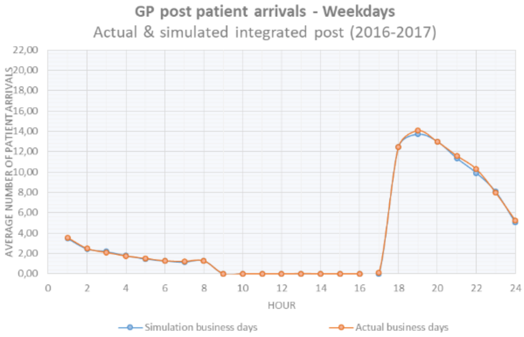
Organization (2016-2017)	Arrival type	ED Label	Absolute frequencies			Relative frequencies		
			Records	Simulation	Difference	Records	Simulation	Difference
GP post	self-referrals	-	6962	6753	-3%	0,073	0,071	0%
	caller	-	88234	88804	1%	0,927	0,929	0%
ED	self-referral	Labeled	-	-	-	-	-	
	self-referral	Unlabeled	2257	2196	-3%	0,048	0,046	0%
	external referral	Labeled	18787	19132	2%	0,401	0,404	0%
	external referral	Unlabeled	13122	13305	1%	0,280	0,281	0%
	GP post referral	Labeled	9017	9009	0%	0,193	0,190	0%
	GP post referral	Unlabeled	3631	3688	2%	0,078	0,078	0%

Table 72: Verification of the patient arrivals within the IEP Enschede (2016-2017).

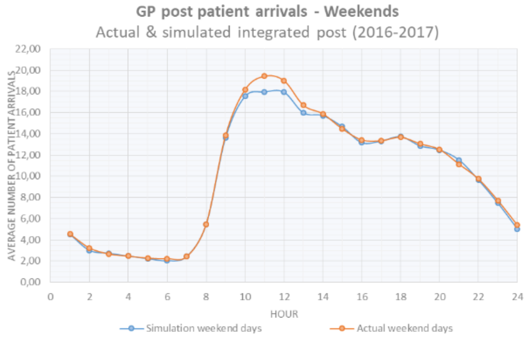
The simulation model's patient arrival rates are determined for each hour separately. The weekdays and the weekends included different arrival patterns, therefore the arrival rates are determined for these two sets separately. No significant differences could be found between the actual and simulated hourly arrival rates for both the GP post and the ED (Figure 90).

R.2.2. Care pathways

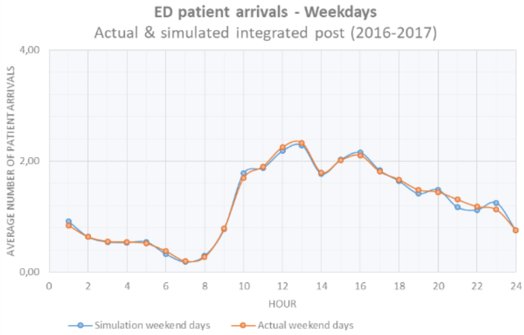
The absolute and relative allocations of both the GP post and the ED care pathways are visualized in. The allocation of the ED's care pathways seem not to differ significantly, only the number of external referrals is slightly overestimated in comparison with the external self-referrals. Most of the GP post care pathways are also allocated quite accurately. However, the absolute frequencies of the A1 and B2 care pathways are slightly different. However, the differences are considered to be acceptable because of the relative low frequencies of these two care pathways, the absolute differences are not that high (-49 versus +91 respectively for two years). The relative frequencies are the same for both the GP post and ED care pathways allocations.



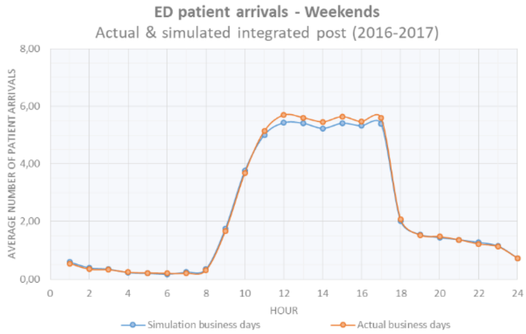
a) GP post weekday arrivals (from Monday until Friday)



b) GP post weekend arrivals (Saturday and Sundays)



c) ED weekday arrivals (from Monday until Friday)



d) ED weekend arrivals (Saturday and Sundays)

Figure 90: Comparison of the actual and simulated hourly patient arrivals, visualized by the blue and red graphs respectively.

A-path integrated (2016-2017)		Absolute frequencies			Relative frequencies		
		Records	Simulation	Difference	Records	Simulation	Difference
A1	IEP self-referral - physical triage - ED consult	854	801	-6%	0,009	0,008	0%
A2	IEP self-referral - physical triage - home	733	722	-2%	0,008	0,008	0%
A3	IEP self-referral - physical triage - GP post consult	5375	5230	-3%	0,056	0,055	0%
A4	Caller - telephonic triage - home	32220	32220	0%	0,338	0,337	0%
A5	Caller - telephonic triage - ED consult	3737	3841	3%	0,039	0,040	0%
A6	Caller - telephonic triage - GP visit - home	7388	7447	1%	0,078	0,078	0%
A7	Caller - telephonic triage - GP visit - ED consult	393	387	-2%	0,004	0,004	0%
A8	Caller - telephonic triage - GP consult	36949	37320	1%	0,388	0,391	0%
A9	Caller - telephonic triage – tel. consult - home	7547	7589	1%	0,079	0,079	0%
B1	GP post consult - home	32497	33084	2%	0,768	0,778	1%
B2	GP post consult - X-ray - home	1782	1798	1%	0,042	0,042	0%
B3	GP post consult - X-ray - ED consult	381	392	3%	0,009	0,009	0%
B4	GP post consult - ED consult	7664	7276	-5%	0,181	0,171	-1%
C1	ED consult – home	22730	23018	1%	0,486	0,486	0%
C2	ED consult – hospital admission	24084	24312	1%	0,514	0,514	0%
X1	ED external referral - ED consult	31909	32437	2%	0,682	0,685	0%
X2	ED self-referral - ED consult	2257	2196	-3%	0,048	0,046	0%
X3	GP post referral - ED consult	12648	12697	0%	0,270	0,268	0%

Table 73: Verification of the care pathway allocations made within the IEP Enschede (2016-2017).

R.2.3. Urgency classifications

The GP post's and ED's urgency classifications for the integrated emergency care in Enschede are visualized in Table 74. The GP post's simulated urgency classifications are not significantly different from the actual urgency classifications, the differences are mainly explained by the small increase in the total number of GP post patients simulated. The ED's urgency classifications assigned are also relatively the same for both the actual and simulated system. Only the number of U0 patients simulated is slightly increased (+5%), but the absolute number is too small to conclude that the differences are significant. The relative frequencies are the same for the GP post and the ED.

Urgency classification (2016-2017)		Absolute frequencies			Relative frequencies		
		Records	Simulation	Difference	Records	Simulation	Difference
GP post	U0	-	-	-	-	-	-
	U1	2189	2231	2%	0,023	0,023	0%
	U2	13724	13898	1%	0,144	0,145	0%
	U3	38505	38475	0%	0,405	0,403	0%
	U4	14424	14462	0%	0,152	0,151	0%
	U5	26338	26491	1%	0,277	0,277	0%
ED	U0	599	566	-6%	0,013	0,012	0%
	U1	6658	6687	0%	0,140	0,141	0%
	U2	21120	20934	-1%	0,445	0,443	0%
	U3	17635	17693	0%	0,372	0,374	0%
	U4	1427	1421	0%	0,030	0,030	0%
	U5	-	-	-	-	-	-

Table 74: Verification of the urgency classifications assigned within the IEP Enschede (2016-2017).

R.2.4. ED treatment groups

The ED treatment group allocations are visualized in Table 75, no significant differences can be found in between the actual and simulated number of treatment group allocations.

ID	Treatment group (2016-2017)	Absolute frequencies			Relative frequencies		
		Records	Simulation		Records	Simulation	Difference
S1	Surgery	22263	22571	1%	0,476	0,477	0%
S2	Internal medicine	6335	6421	1%	0,135	0,136	0%
S3	Neurology	4405	4349	-1%	0,094	0,092	0%
S4	Orthopedics	3913	3883	-1%	0,084	0,082	0%
S5	Pulmonary medicine	4612	4754	3%	0,099	0,100	0%
S6	Gastrointestinal & liver	2902	2904	0%	0,062	0,061	0%
S7	Other	2384	2448	3%	0,051	0,052	0%

Table 75: Verification of the patient arrivals within the IEP Enschede (2016-2017).

R.2.5. Processing times

The durations of all activities simulated are stored within a separate table file, which makes it possible to generate the mean and variance for all durations (Table 76). No significant differences can be found for almost all activities. The duration of a physical consult conducted by a GP is slightly overestimated by the simulation model. The small difference is acceptable however, because it partly compensates the implications of the assumption that no idle time is present within the simulation model. Both the CT scan duration and CT waiting time include a larger variability within the simulation model in comparison with the real-world durations.

		Actual durations		Simulated durations		Difference	
Organization	**activity**	**Mean**	**Stdev**	**Mean**	**Stdev**		
GP post	Telephonic triage					0%	-6%
	Physical triage					-2%	-4%
	GP physical consult					-1%	-2%
	GP visit					0%	-2%
	GP driving duration	**CONFIDENTIAL**				1%	-7%
	GP telephonic consult					0%	-4%
	NP consult					-2%	-2%
	GP assistant consult					-6%	-7%
ED	Physical triage					-1%	-2%

	CT scan waiting		3%	6%
	CT scan duration		0%	17%
	Ultrasound waiting		2%	2%
	Ultrasound duration		-5%	8%
	X-ray waiting		0%	-1%
	X-ray duration		-2%	-1%

Table 76: Comparison between the mean and standard deviation of all actual and simulated activities' durations (2016-2017).

Appendix S – Solution validation output variables

All KPIs discussed in this appendix result from the simulation model, no real KPI values are discussed.

S.1. New model versus new data

Organization	Activity	Waiting time Separated (2014-2015)	Waiting time Integrated (2016-2017)
GP post	Telephonic triage	00:00:07	00:00:11
	Physical triage	00:00:15	00:01:19
	GP visit home	00:45:05	00:39:43
	Wait for appointment	00:26:16	00:23:07
	GP physical consult	00:18:33	00:18:09
	GP telephonic consult	00:16:52	00:15:08
	NP physical consult	00:09:44	00:11:17
	GP assistant physical consult	00:06:16	00:07:10
ED	Physical triage	00:00:28	00:04:11
	Anamnesis 1 – nurse	00:01:17	00:00:34
	Anamnesis 2 – resident	00:19:32	00:19:20
	Ultrasound	00:04:43	00:04:23
	Lab	00:02:30	00:02:12
	X-ray	00:06:16	00:04:04
	ECG	00:01:48	00:01:37
	CT	00:04:09	00:02:50
	Treatment	00:43:46	00:48:47
	Plaster	00:23:30	00:34:38

Organization	Staff member	Utilization Separated (2014-2015)	Utilization Integrated (2016-2017)
GP post	Nurse practitioner	27,1%	32,7%
	Telephonic GP assistant	28,8%	31,7%
	Physical triage assistant	6,3%	20,0%
	Coordinating GP assistant	12,5%	15,8%
	General practitioner	52,5%	49,4%
	Circulating GP assistant	2,6%	8,0%
ED	Nurse	17,8%	19,2%
	Physical triage nurse	16,3%	33,6%
	Directing nurse	2,8%	11,3%
	Emergency physician	57,5%	49,0%
	Resident 1 – Surgery & Orthopedics	49,0%	53,8%
	Resident 2 – Internal medicine	20,9%	24,9%
	Resident 3 – Neurology	33,9%	37,7%
	Resident 4 – Pulmonary medicine	32,1%	38,8%

S.2. Old model versus new data

Organization	Activity	Waiting time Separated (2014-2015)	Waiting time Integrated (2016-2017)
GP post	Telephonic triage	00:00:08	00:00:15
	Physical triage	00:00:04	00:01:35
	GP visit home	11:39:31	08:18:20
	Wait for appointment	00:39:16	00:35:55
	GP physical consult	00:42:20	00:40:40
	GP telephonic consult	-	-
	NP physical consult	00:42:20	00:40:40
	GP assistant physical consult	00:42:20	00:40:40
ED	Physical triage	00:01:19	00:20:26
	Anamnesis 1 – nurse	00:00:02	00:00:01
	Anamnesis 2 – resident	00:17:20	00:08:39
	Ultrasound	00:03:56	00:02:53
	Lab	00:00:26	00:00:22
	X-ray	00:01:40	00:03:15
	ECG	00:00:22	00:00:19
	CT	00:07:57	00:05:04
	Treatment	00:12:38	00:07:36
	Plaster	00:01:18	00:00:11

Organization	Staff member	Utilization Separated (2014-2015)	Utilization Integrated (2016-2017)
GP post	Nurse practitioner	54,2%	49,6%
	Telephonic GP assistant	28,1%	32,4%
	Physical triage assistant	6,1%	19,9%
	Coordinating GP assistant	12,0%	15,9%
	General practitioner	67,0%	66,0%
	Circulating GP assistant	37,0%	34,0%
ED	Nurse	18,6%	17,9%
	Physical triage nurse	20,1%	44,4%
	Directing nurse	0,6%	0,3%
	Emergency physician	43,5%	31,5%
	Resident 1 – Surgery & Orthopedics	54,9%	49,8%
	Resident 2 – Internal medicine	3,6%	3,8%
	Resident 3 – Neurology	10,7%	7,8%
	Resident 4 – Pulmonary	11,4%	9,4%

S.3. New model versus old data

Organization	Activity	Waiting time Separated (2014-2015)	Waiting time Integrated (2016-2017)
GP post	Telephonic triage	00:00:11	00:00:12
	Physical triage	00:00:24	00:01:11
	GP visit home	01:38:21	01:43:48
	Wait for appointment	01:27:08	01:19:51
	GP physical consult	00:19:33	00:27:55
	GP telephonic consult	-	-
	NP physical consult	00:06:48	00:06:53
	GP assistant physical consult	-	-
ED	Physical triage	00:00:27	00:00:30
	Anamnesis 1 – nurse	00:07:17	00:40:27
	Anamnesis 2 – resident	00:31:15	01:01:02
	Ultrasound	00:06:22	00:07:38
	Lab	00:02:25	00:02:28
	X-ray	00:03:02	00:03:16
	ECG	00:01:40	00:01:38
	CT	00:02:10	00:02:05
	Treatment	00:56:15	01:18:25
	Plaster	00:36:19	01:02:13

Organization	Staff member	Utilization Separated (2014-2015)	Utilization Integrated (2016-2017)
GP post	Nurse practitioner	4,7%	25,9%
	Telephonic GP assistant	43,3%	44,5%
	Physical triage assistant	13,2%	25,3%
	Coordinating GP assistant	25,2%	26,5%
	General practitioner	69,7%	75,5%
	Circulating GP assistant	-	-
ED	Nurse	13,7%	13,4%
	Physical triage nurse	21,4%	18,9%
	Directing nurse	2,4%	1,5%
	Emergency physician	21,0%	11,2%
	Resident 1 – Surgery & Orthopedics	66,6%	72,2%
	Resident 2 – Internal medicine	42,4%	23,0%
	Resident 3 – Neurology	8,0%	22,9%
	Resident 4 – Pulmonary medicine	18,4%	19,3%

S.4. New model – separated & data 2016-2017

Organization	Activity	Waiting time Integrated (2016-2017)	Waiting time Separated (2016-2017)
GP post	Telephonic triage	00:00:11	00:00:10
	Physical triage	00:01:19	00:00:11
	GP visit home	00:39:43	00:33:23
	Wait for appointment	00:23:07	00:22:14
	GP physical consult	00:18:09	00:16:42
	GP telephonic consult	00:15:08	00:11:41
	NP physical consult	00:11:17	00:11:03
	GP assistant physical consult	00:07:10	00:08:15
ED	Physical triage	00:04:11	00:05:18
	Anamnesis 1 – nurse	00:00:34	00:01:31
	Anamnesis 2 – resident	00:19:20	00:29:41
	Ultrasound	00:04:23	00:04:15
	Lab	00:02:12	00:02:13
	X-ray	00:04:04	00:04:05
	ECG	00:01:37	00:01:38
	CT	00:02:50	00:02:56
	Treatment	00:48:47	00:53:35
	Plaster	00:34:38	00:46:12

Organization	Staff member	Utilization Integrated (2016-2017)	Utilization Separated (2016-2017)
GP post	Nurse practitioner	32,7%	28,4%
	Telephonic GP assistant	31,7%	31,2%
	Physical triage assistant	20,0%	7,2%
	Coordinating GP assistant	15,8%	15,2%
	General practitioner	49,4%	46,5%
	Circulating GP assistant	8,0%	7,1%
ED	Nurse	19,2%	21,6%
	Physical triage nurse	33,6%	36,5%
	Directing nurse	11,3%	12,1%
	Emergency physician	49,0%	65,5%
	Resident 1 – Surgery & Orthopedics	53,8%	60,8%
	Resident 2 – Internal medicine	24,9%	24,2%
	Resident 3 – Neurology	37,7%	35,2%
	Resident 4 – Pulmonary medicine	38,8%	37,1%

Appendix T – Data modifications (2014-2017)

The simulation model developed by Koster (2014) does not include all the components of today's conceptual model. Therefore, simply copying all today's input variables will not work. Several modifications are required in order to make the simulation model work properly:

- The model developed by Koster was used to simulate the out-of-hours emergency care only. Some utilization issues arise if the same model is used to simulate the ED 24/7. The GP visits' utilization rates are near 100%, which increases the number of waiting patients at home unrestrained. This behavior is unrealistic and negatively influences the staff availability at the GP post itself, especially if all these patient remain waiting if the GP post is closed. Therefore, all patients waiting more than one full day are removed;
- The integrated simulation model developed by Koster does not allow any self-referral to arrive at the ED, even if the GP post is closed. Koster only simulated the out-of-hours emergency care organization, which explains the absence of self-referrals at the ED in between 8:00am and 5:00pm during weekdays. Therefore, the X-path patients arriving in 2016 and 2017 includes all the ED's self-referrals and external referrals. The modified treatment groups allocations (Figure 91a) and urgency allocations (Figure 91b) are also aggregated into one table file. For the separated organization in 2014 and 2015, a total of 10403 self-referrals arrived in comparison with 91539 GP post arrivals. Therefore, 7.20% of all the patient arrivals are self-referred to the ED immediately (excluding the ED's externally referred patients);

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a) Separated emergency organization (2014-2015). *b) ED urgency classifications (2016-2017).*

Figure 91: The modified ED's treatment group and urgency allocations in order to activate Koster's simulation model, including today's input variables (2016-2017). Both figures include the ED's self- & external referrals only

- The inclusion of the new A-path 'Telephonic GP consult (A9) cannot be added to the simulation model without some hard coding. Therefore, all these patients are added to the A-path 'Physical GP consult' (A8);
- The NP and GP assistants are still available to conduct a physical consult at the GP post. However, Koster's model does not include the possibility to make these type of staff allocations based on historical data. Therefore, the NP and GP assistants are allocated to the treatment of non-urgent patients only (U3 or U4);

- No unlabeled GP post referrals are allowed in the simulation of Koster (2014). Therefore, the label classifications of the external and GP post referrals are recalculated from the patient records (Table 77);

Separated organization (2014-2015)					
Classification	**ED urgency classification**				
	U0	U1	U2	U3	U4
Labeled	0,038	0,313	0,633	0,916	0,909
Unlabeled	0,962	0,687	0,367	0,084	0,091

a) Separated emergency organization (2014-2015).

Integrated organization (2016-2017)					
Classification	**ED urgency classification**				
	U0	U1	U2	U3	U4
Labeled	0,024	0,200	0,585	0,840	0,898
Unlabeled	0,976	0,800	0,415	0,160	0,102

b) Integrated emergency organization (2016-2017).

Table 77: Relative frequencies of the ED's label classification separated per urgency classification.

- Koster's simulation model cannot include separate duration factors for all GP post activities, as described in section 6.4.3. Therefore, an average factor is determined for all five urgency classifications (*Table 3*), these values can be implemented in the "Urgentie" table file.

Code	Color	Separated factor GP post	Integrated factor GP post
U0	Red	0.55	0.46
U1	Orange	1.57	1.47
U2	Yellow	1.24	1.14
U3	Green	0.91	0.84
U4	Blue	0.48	0.68

Table 78: ED LOS factors in order to differentiate the durations for each urgency classification.

- Koster's model included a separated care pathway dedicated for plaster requirements. However, today's treatment group allocations do not take these patients into account as one individual entity. Therefore, a variable is implemented which represents the probability that a patient requires plaster. This variable is only used by surgery and orthopedic patients, 24.5% of all these patients receive plaster in between 2016-2017;
- No distinction is made between the unlabeled patients arriving via the main entrance or arriving by ambulance, trauma helicopter or police. Therefore, all patients should be seen first by the triage nurse in the dedicated physical triage room. No physical triage is conducted at the treatment rooms itself;
- Not all the ED residents are full time available, which contradicts with the assumptions made by Koster (2014). Nowadays, the surgery and/or orthopedic residents take over the treatments for which no other resident is available. However, these take overs depend on the time of day, which cannot be included into Koster's model. Therefore, it is assumed that the surgery/orthopedic residents can always take care of labeled and unlabeled patients.
- Not all probability functions required for the generation of patient arrivals and activity durations are included within the model made by Koster. The missing probability functions are simply added to the corresponding methods, because the overall decision logic is not influenced by these lines of code.
- A bug was present in the simulation model developed by Koster (2014). Sometimes the ED treatment room was not made available again once the patients leaved the hospital. Therefore, the number of available rooms decreased over time, while these rooms were not occupied at all. This bug is eliminated by implementing an availability check once a patient leaves the hospital. This will free the ED treatment room if possible, while all other decision logic is not interfered;
- Koster's model allowed the ED patients to interchange the room allocations after each activity. This is not allowed in real-life, therefore, most treatment rooms are generalized. Only the trauma rooms, diagnostic rooms, plaster rooms and fast track room are differentiated;

- A bug was present in the simulation model developed by Koster (2014) regarding the transfer of plaster patients. If the patient was already allocated to another treatment room, the patient could not enter the plaster room. Three lines of code are added to the method “EndStage” in order to free the rooms appropriately.

The GP post appointment strategy does not include the usage of time slot allocations. The ED triage nurses do not support the GP post physical triage of self-referrals arriving during the night. ED residents cannot be called from an external department and the ED’s emergency physicians cannot transfer the responsibility over the patient’s treatment to another staff member. Finally, no differences are taken into account into the travel time required for the diagnostic employees to arrive at the ED. However, the underlying decision logic programmed by Koster (2014) is not changed, otherwise the model’s solutions are not truly validated. Only minor modifications were made in order to make the simulation model bug free. For example, the ED patients were allowed to be allocated to a new room once the previous activity was completed. A bug was also included regarding the allocation of plaster patients once the patient was allocated to another type of treatment room.

Appendix U – Data analytics Koster (2012-2013)

This appendix includes all the input variables used by Koster in her simulation research in 2014. The input variables are based on the patient records from both the GP post and the ED in between 2012 and 2013. The same format of chapter 5 is used to discuss each type of input variable. First the patient arrivals will be discussed. Secondly, the GP post patients' characteristics are discussed in more detail, followed by the ED patients' characteristics. Finally, the resource allocations and durations will be elaborated in more detail.

U.1. Patient arrivals

U.1.1. Hour factor α_h

The GP post's and ED's patient arrival patterns observed in between 2012 and 2013 by Koster were pretty accurate in comparison with today's data (Figure 92 and Figure 93). The arrival distributions' shapes remained the same over the years, but the average arrival rates decreased over the years for all hour intervals. The actual GP post arrival rates include two patients less approximately in comparison with the predictions made by Koster, especially the weekends resulted to be less busy as expected. The number of ED patient arrivals also decreased over the years. However, Koster expected that the ED patient arrivals would drop more due to the integration with the GP post.

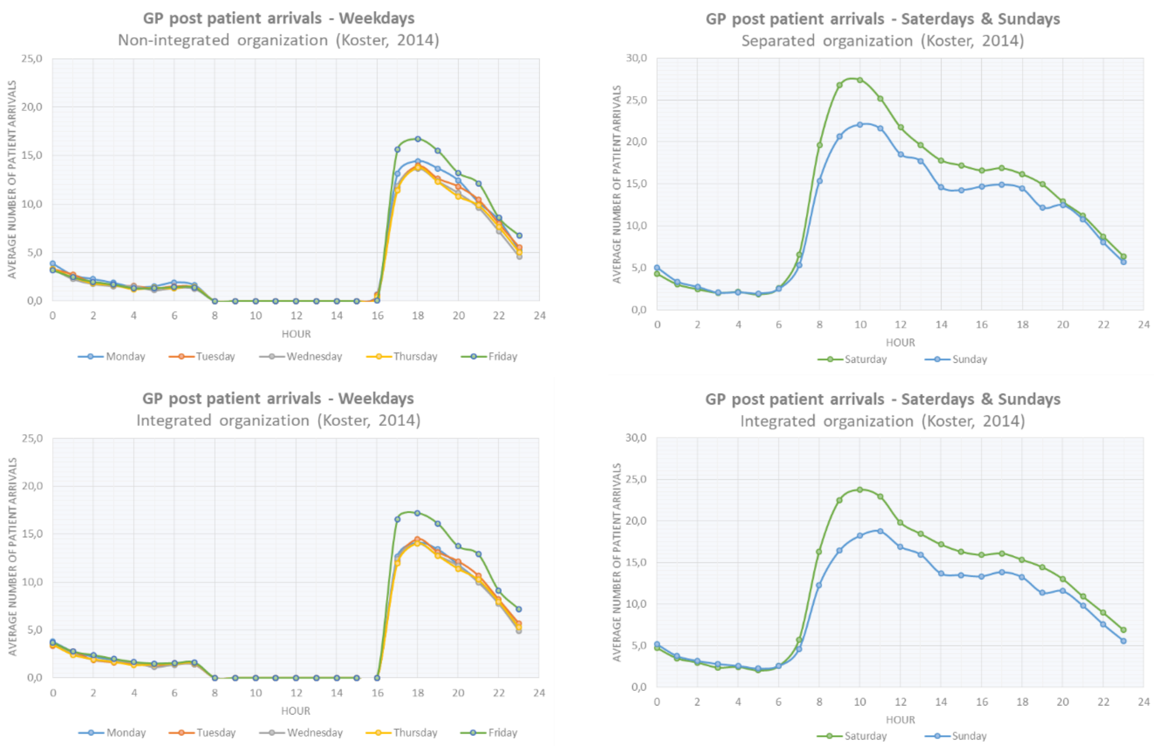


Figure 92: A visualization of the GP post's average daily patient arrivals observed by Koster (2014) for the period 2012-2013. The two bottom figures represent the expected GP post patient arrival patterns for the integrated organization, including the ED's self-referrals during out-of-office hours.

Figure 93: A visualization of the ED's average daily patient arrivals observed by Koster (2014) for the period 2012-2013. The two bottom figures represent the expected ED patient arrivals for the integrated organization, excluding the ED's self-referrals during out-of-office hours. The GP post referrals are excluded from the data.

U.1.2. Day factor βd

Table 79 includes the daily factors estimated by Koster (2014). The daily factors include slightly different values in comparison with the results discussed in chapter 5. The grouping of days resulted to be the same approximately, but the weekly deviations resulted to be smaller than expected. Mondays and Fridays are also busier in comparison with the midweek, while Saturdays include more patient arrivals in comparison with the Sundays.

Organization type	Day(s) of the week	Distribution	Parameter 1	Parameter 2
Separated GP post (2012-2013)	Monday	Normal	1,004	0,128
	Tuesday, Wednesday & Thursday	Normal	0,956	0,133
	Friday	Lognormal	1,126	0,175
	Saturday	Lognormal	1,000	0,105
	Sunday	Gamma	79,433	0,013
Integrated GP post (2014)	Monday	Normal	1,002	0,128
	Tuesday, Wednesday & Thursday	Normal	0,950	0,147
	Friday	Lognormal	1,144	0,191
	Saturday	Lognormal	1,000	0,112
	Sunday	Gamma	1,000	0,123
Separated ED (2012-2013)	Monday & Friday	Lognorm	1,069	0,159
	Tuesday, Wednesday & Thursday	Normal	0,953	0,161
	Saturday & Sunday	Lognorm	1,000	0,268
Integrated ED (2014)	Monday & Friday	Lognorm	1,060	0,125
	Tuesday, Wednesday & Thursday	Normal	0,958	0,117
	Saturday & Sunday	Normal	1,000	0,124

Table 79: Estimated probability functions underlying the GP post's and ED's daily arrival factors. These factors are determined for the separated and integrated out-of-hours emergency care organization. Two parameters are required to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ), while the "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β).

U.1.3. *Week factor Υ_w*

Koster (2014) also assumed that no seasonal effects were present in the GP post's and ED's weekly patient arrivals. Only the input parameters and underlying probability distribution are allocated differently. The reader is referred to Koster's report for data comparisons.

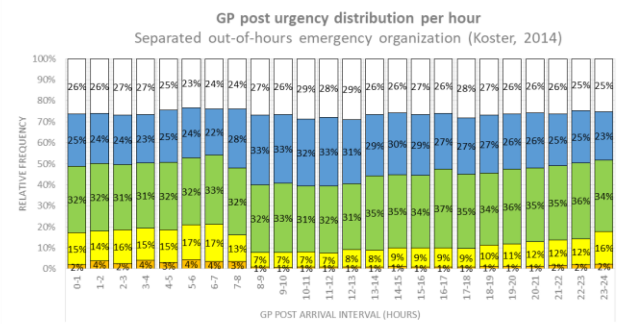
Organization type	Distribution	Parameter 1	Parameter 2
Separated GP post (2012-2013)	Lognormal	1,004	0,112
Integrated GP post (2014)	Lognormal	1,000	0,106
Separated ED (2012-2013)	Weibull	14,573	1,035
Integrated ED (2014)	Normal	1,001	0,087

Table 80: Estimated probability functions underlying the GP post's and ED's weekly arrival factors. These factors are determined for the separated and integrated out-of-hours emergency care organization. Only two parameters are required to describe the "normal" and "lognormal" distribution, the mean (μ) and standard deviation (σ). while the "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β).

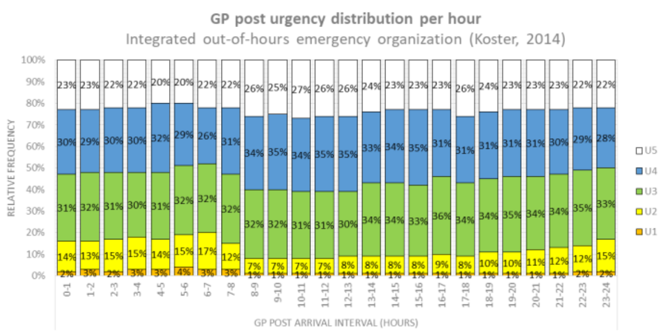
U.2. GP post patient characteristics

U.2.1. *GP post urgency classifications*

Koster observed the same type of GP post urgency classifications per hour as today. Back in 2012 and 2014, more low urgent patients were arriving at the GP post for medical assistance (U4 patients). Over the years, the number of high- and intermediate urgent patients contacting the GP post have increased relatively, as discussed in chapter 5. Koster expected that the low urgent patients (U4 and U5) would contact the GP post more often due to the integration, which resulted not to be the case. The frequency of non-urgent patients (U5) remained remarkably the same for all six years taken into consideration.

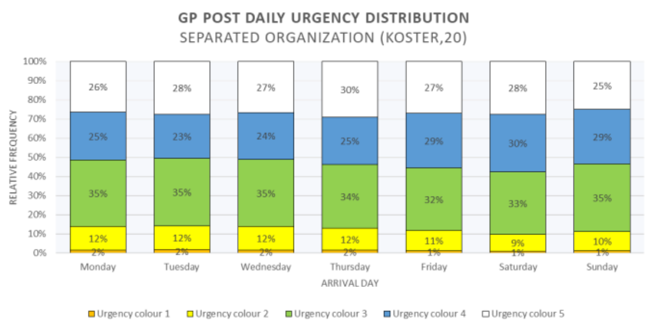


c) Separated emergency care organization observed by Koster (2012-2013).

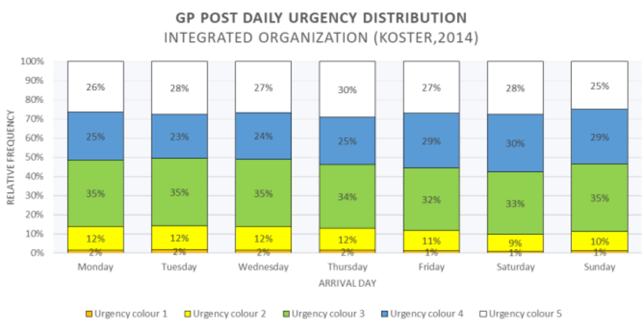


d) Integrated emergency care organization expected by Koster (2014).

Figure 94: The urgency classifications allocated to the patients arriving at the GP post per hour.



c) Separated emergency care organization (Koster,2014).

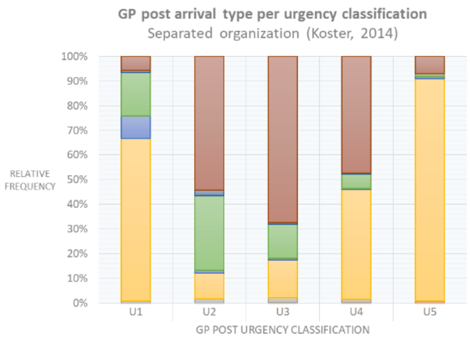


b) Integrated emergency care organization (Koster,2014).

Figure 95: The urgency classifications allocated to the patients arriving at the GP post per day.

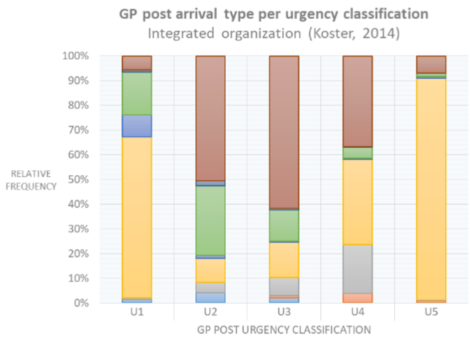
U.2.2. Entrance GP post (path A)

*Figure 29*a and *Figure 29*b visualize the A-path distributions observed and expected by Koster (2014) for both the separated and integrated out-of-hours emergency care organizations respectively. The frequencies result to be approximately the same as for the arrival patterns given in chapter 5. However, some differences can be observed by looking at the frequency values more closely. First of all, Koster expected that the relative number of physical consults would be lower for all types of urgency classifications due to the integration. This decrease in the relative allocation of GP post consults indeed happened, but less than expected. Secondly, the number of telephonic advises in between 2014 and 2017 is relatively large for all urgency classifications, while these activities were not expected by Koster at all. Thirdly, the high-urgent patients are less often forwarded to the ED after triage over the years, it is even remarkable that the patients are more often helped by offering advice. Finally, the number of GP post visits increased over the years.



	U1	U2	U3	U4	U5
A9	0,000	0,000	0,000	0,000	0,000
A8	0,057	0,543	0,673	0,474	0,070
A7	0,010	0,022	0,009	0,003	0,000
A6	0,174	0,303	0,138	0,059	0,012
A5	0,091	0,011	0,006	0,005	0,007
A4	0,660	0,104	0,154	0,445	0,901
A3	0,008	0,017	0,021	0,012	0,003
A2	0,000	0,000	0,001	0,002	0,006
A1	0,000	0,000	0,000	0,000	0,000

a) Separated out-of-hours emergency organization expected by Koster (2014)



	U1	U2	U3	U4	U5
A9	0,000	0,000	0,000	0,000	0,000
A8	0,056	0,506	0,617	0,368	0,070
A7	0,010	0,020	0,008	0,002	0,000
A6	0,172	0,283	0,126	0,046	0,012
A5	0,090	0,010	0,005	0,004	0,007
A4	0,651	0,097	0,141	0,345	0,899
A3	0,008	0,043	0,075	0,197	0,003
A2	0,000	0,000	0,009	0,039	0,008
A1	0,013	0,041	0,020	0,000	0,000

b) Integrated out-of-hours emergency organization expected by Koster (2014)

Figure 96: The distribution of the care pathways into the GP post for both the separated and integrated out-of-hours emergency care, including the ED self-referrals. The A-path ratios are determined for each urgency classification separately.

U.2.3. GP post physical consult

Koster (2014) did not based the allocation of GP assistants and NPs on the historical data obtained from the patient records. The assumption is made that these type of staff allocations are allowed for non-urgent patients only (U4 and U5). Therefore, no data input is required.

U.2.4. GP post departure types (path B)

The GP post's departure frequencies differ a lot from the frequencies observed and expected by Koster (2014). Previous research observed that the number of patients going home directly in between 2012 and 2013 is the same as observed in between 2014 and 2015. Koster expected that the more patients would be referred to the ED or diagnostic department due to the integration, but this resulted not to be true (Table 81). Over the year, less patients are referred to the radiology department, and the radiology department refers less patients to the ED. Therefore, the number of GP post referrals decreased relatively in between 2012 and 2017.

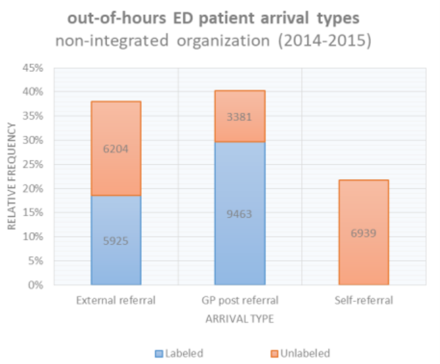
B-path	GP post departure type	Data Koster (2014)	
		Separated (2014-2015)	Integrated (2016-2017)
B1	Go home directly	0,741	0,648
B2	Via X-ray to home	0,056	0,078
B3	Via X-ray to ED	0,031	0,078
B4	Referred to ED	0,172	0,196
Total		1,000	1,000

Table 81: Relative frequencies of the GP post's departures expected by Koster (2014) for both the separated and integrated out-of-hours emergency care organization in Enschede.

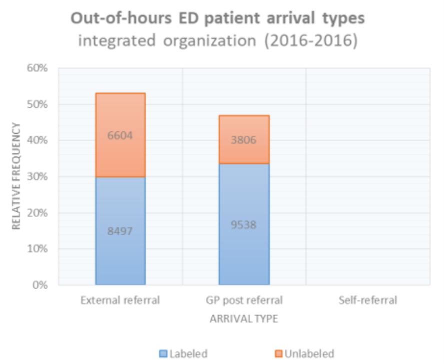
U.3. ED patient characteristics

U.3.1. ED arrival types

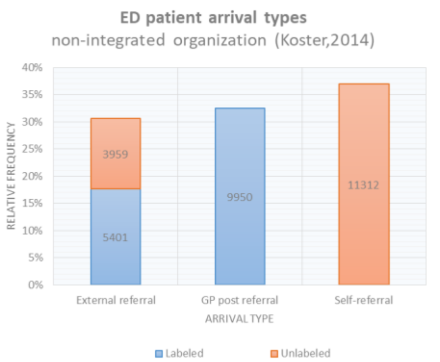
Koster (2014) only investigated the out-of-hours emergency care in Enschede, while the histograms in paragraph 3.2.2. described the arrival of all ED patients 24/7. The out-of-hours ED arrivals in between 2014 and 2017 are also visualized (Figure 97) in order to make useful comparisons between the arrivals observed/expected by Koster and the arrivals actually realized in between 2014 and 2017.



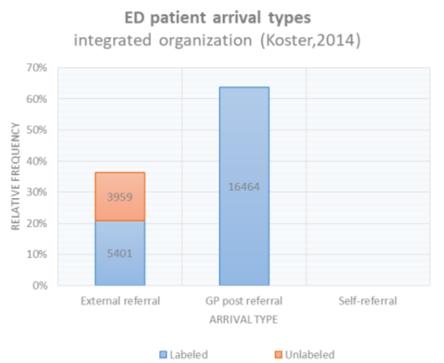
a) Actual ED arrivals during the separated organization. (2014-2015)



b) Actual ED arrivals during the separated organization. (2016-2017)



c) Expected ED arrivals during the separated organization. (Koster, 2014)



d) Expected ED arrivals during the integrated organization. (Koster, 2014)

Figure 97: A comparison between the out-of-hours ED patient arrivals expected by Koster and the actual ED patient arrivals obtained in between 2014 and 2017.

The number of external referrals resulted to be higher than expected by Koster (2014), both for the separated and the integrated out-of-hours emergency care organization. It was also expected that the GP post referrals did not include unlabeled patients at all, which resulted to be not the case. Finally, Koster expected that the number of GP post referrals would increase due to the integration, but this has not happened.

U.3.2. ED treatment groups

The treatment groups' definitions applied within this research are slightly different from the definitions applied by Koster (2014). She distinguished twelve treatment groups in order to model the patients' alternative logistic care paths. The first ten patient groups were already proposed by Visser (2011), while the last two patient groups were personalized to the hospital organization in Enschede due to its function as trauma center.

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

Table 82: The twelve ED treatment groups defined by Koster (2014).

Eight of the treatment groups proposed by Visser (2011) were based on the eight most commonly used "Diagnostis Related Groups" (DRG's) from one year after introducing the IEP in Almelo. Visser also added two residual groups: 1) surgical specialties and 2) contemplative specialties in order to include all patient care paths. The "Surgery & Orthopedics" cluster was only divided into different treatment groups, based on specific entrance complaints. The DRG based treatment groups are useful, because the diagnostic test allocations were already determined by related experts. However, Koster already identified a disadvantage of these classification in 2014 due to missing data. Koster derived the patient's treatment group from the registered entrance complaints resulting from the physical triage. 34.7% of the patient records included wrong complaint selections, which makes it difficult to provide a trustworthy representation of the treatment group distributions. This problem became even worse nowadays due to the modifications of the entrance complaints.

However, the alternative treatment groups defined by Koster can be aggregated into five specialist classifications: 1) Surgery & orthopedics; 2) Neurology; 3) Pulmonary medicine; 4) Internal medicine and 5) all other specialists. These classifications are roughly comparable with the treatment groups defined in today's research. The treatment group distributions in Figure 98 and Figure 99 also indicate that Koster observed that the surgery and orthopedics would take care of most patients in between 2012 and 2013. Koster expected that the pulmonary resident allocations would form the second largest classification used for self-referrals, this resulted to be the neurology resident in practice however. The surgery and orthopedic allocations' frequencies are also expected too high, the internal and pulmonary medicine residents are allocated more frequently.

CONFIDENTIAL

Figure 99: The allocation of ED treatment groups to the GP post referrals expected by Koster (2014).

U.3.3. Diagnostic test requests.

Koster expected that the requests of the radiology department's diagnostic tests would not change due to the integration. The diagnostic tests were more often requested in between 2012 and 2013 in comparison with today (Table 83). The number of CT-scan and ultrasound requests were slightly overestimated, but the relative differences between the alternative treatment groups was predicted correctly. However, the actual X-ray requested in between 2014 and 2017 are significantly different from the expectations made by Koster, especially the number of neurology and gastrointestinal & liver requests were overestimated.

Diagnostic test	Input values	Treatment groups - expectations Koster (2014)						
		Surgery	Internal medicine	Pulmonary medicine	Neurology	Orthopedics	Gastro & liver	Other
X-ray	Probability	19%	70%	95%	50%	19%	70%	50%
	Activity ratio	2,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
CT-scan	Probability	3%	10%	15%	100%	3%	10%	0%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Ultrasound	Probability	19%	15%	0%	0%	19%	15%	5%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Laboratory	Probability	33%	100%	100%	100%	33%	100%	50%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
ECG	Probability	7%	50%	75%	75%	7%	50%	25%
	Activity ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Travel ratio	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Table 83: The probability and duration ratios expected by Koster (2014) for the activity and travel durations of all diagnostic tests per treatment group. The ratios will be used to modify the distributions shape factors.

U.3.4. ED urgency classifications

The urgency distributions expected by Koster (2014) are approximately the same as for the ED patient arrivals in between 2014 and 2017. The surgery & orthopedics residents help U3 (green) patients more often, while the observatory specialists take care of U1 (orange) and U2 (yellow) patients more frequently.

U.3.5. Medical specialist request

The treatment's group residents and emergency physicians are able to contact a medical specialist for diagnostic and treatment related questions. It is even possible that the medical specialist itself visits the ED in order to support the patient's treatment physically. The probability of requesting a medical specialist is assumed to depend on the patient's urgency classification (Koster, 2014). The ED patient records do not include any data regarding these support activities. Therefore, the assumptions made by Koster are evaluated, checked and reused. The probabilities and waiting times are not impacted by the decision to integrate the GP post and the ED.

U.3.6. ED plaster request

Koster developed an alternative treatment group for plaster patients. Therefore, no comparisons could be made directly. However, the plaster treatment group developed by Koster was treated by a surgery or orthopedics resident. Therefore, the plaster requirements are based on the patient records obtained from in between 2014 and 2017.

U.3.7. ED departure types (path C)

The ED's departure types were already discussed in paragraph 3.2.4. *"Patient outflow – ED"*. The ED departure type depends on the patient's urgency classification given by the ED. The number of patient's going home directly decreased for all urgency levels since the integration of the GP post and the ED (*Table 17*). Koster (2014) overestimated the number of patients going home directly.

Separated organization (2014-2015)						
GP post arrival	ED departure type	ED URGENCY CLASSIFICATION				
		U0	U1	U2	U3	U4
C1	Home	0,027	0,210	0,454	0,863	0,890
C2	Hospitalization	0,973	0,790	0,546	0,137	0,110

a) separated out-of-hours emergency organization, based on the most recent data (2014-2015).

Integrated organization (2016-2017)						
ID	ED departure type	ED URGENCY CLASSIFICATION				
		U0	U1	U2	U3	U4
C1	Home	0,018	0,198	0,414	0,802	0,849
C2	Hospitalization	0,982	0,802	0,586	0,198	0,151

b) Integrated out-of-hours emergency organization, based on the most recent data (2016-2017).

Separated organization (Koster,2014)						
ID	ED departure type	ED URGENCY CLASSIFICATION				
		U0	U1	U2	U3	U4
C1	Home	0,132	0,202	0,511	0,927	0,904
C2	Hospitalization	0,869	0,798	0,489	0,073	0,096

c) Separated out-of-hours emergency organization, expected by Koster (2014).

Integrated organization (Koster,2014)						
ID	ED departure type	ED URGENCY CLASSIFICATION				
		U0	U1	U2	U3	U4
C1	Home	0,118	0,149	0,433	0,867	0,839
C2	Hospitalization	0,882	0,851	0,567	0,133	0,161

d) Integrated out-of-hours emergency organization, expected by Koster (2014).

Table 84: Relative frequencies of the ED's departure types separated per urgency classification (Path C).

U.4. Activity durations

U.4.1. GP post processing times

Table 85 provides the GP post durations expected by Koster (2014). It can be concluded that all activities' durations increased over the years. The average physical GP consult duration increased from 10 minutes to 12 minutes, which as implications for the appointment strategy applied within the GP post. The NP resulted to work faster than expected however.

		Expectations Koster (2014)				
GP post activity	**Distribution**	**Parameter 1**	**Parameter 2**	**µ**	**Min**	**Max**
Telephonic triage	Normal	CONFIDENTIAL				
Physical triage	Gamma					
GP physical consult	Lognormal					
GP visit	Lognormal					
GP driving duration	Lognormal					
GP telephonic consult	-					
NP consult	Deterministic					
GP assistant consult	-					

Table 85: The GP post durations expected by Koster (2014). Two parameters are required in order to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ). The "weibull" and "gamma" distribution require the shape factor (α) and scale factor (β).

U.4.2. ED processing times

Table 86 provides the diagnostic test durations and travel times expected by Koster (2014). It can be concluded that the CT scan and ultrasound durations were pretty good estimated. Only the X-ray diagnostic requests include more time in practice. On the other hand, Koster did not take the alternative travel and activity durations into account for each treatment group.

		Expectations Koster (2014)				
ED activity	**Distribution**	**Parameter 1**	**Parameter 2**	**µ**	**Min**	**Max**
CT scan waiting	Normal	CONFIDENTIAL				
CT scan duration	Normal					
Ultrasound waiting	Deterministic					
Ultrasound duration	Normal					
X-ray waiting	Normal					
X-ray duration	Deterministic					

Table 86: The ED durations expected by Koster (2014). Two parameters are required in order to describe the activities hypothesized distribution function. The "normal" and "lognormal" distribution require the mean (μ) and standard deviation (σ). The deterministic results include the mean only.

U.5. Staff & room allocations

U.5.1. Physical triage staff allocations

Koster didn't recognized this type of configuration, she expected that all self-referrals were first seen by a GP post triage nurse. Therefore, the labeled/unlabeled observed by Koster are used in order to determine in which room the triage is conducted, which means that GP post patients are referred to the dedicated triage room.

U.5.2. GP post physical consult

Koster expected the same type and number of staff allocations, except for the GP assistant that is also used for physical consults. The GP assistant is eliminated from all staff allocations. On the other hand, the GP post is expended with an NP in order to maintain feasibility, otherwise the GP post LOS would increase too much because of overutilization of the GP post's resources.

U.5.3. ED treatment group staff allocations

Koster included the same type of residents within her simulation study in 2014. She included one additional resident type, because more treatment groups were included. She also allowed the emergency physician to treat both labeled surgery and labeled orthopedic patients. Finally, only the emergency physicians were allowed to treat unlabeled patients, mainly because it was assumed that these staff members were always present.

U.5.4. ED staff availability

Koster (2014) expected that residents would be more available for an ED consult. She expected that all resident types were available during the out-of-hours emergency care. All resident types included one staff member only, the emergency physician could have two members present at the same time.

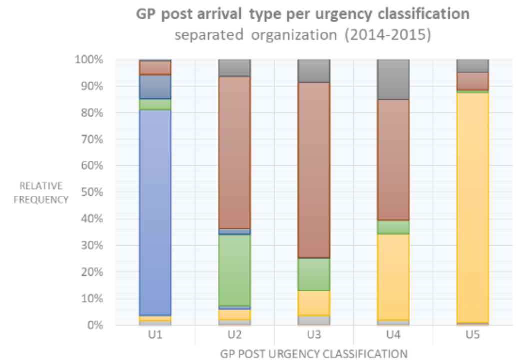
U.6. Unavailable data modifications

Note that today's simulation model includes more input variables in comparison with the model developed by Koster (2014). Therefore, most input variables are updated by the values found in the patient records originating from 2012 and 2013. However, today's input variables are used if the variables cannot be obtained from the patient record and simulation model used by Koster. For example, the allocation of NP and GP assistants changed too much, the data inputs of 2012 and 2013 could not fit in the new simulation model's format anymore. The data regarding the ED's triage support during the night and the GP post activity durations' factors per urgency classification are still based on the data of 2014 up and till 2017. The same applies to the inclusion of self-referrals within the X-path, the transfer of responsibility by the emergency physicians, the implementation of alternative plaster probabilities for each treatment group and the travel times required from residents to arrive at the ED from an external department.

Appendix V – Data modifications separated organization (2016-2017)

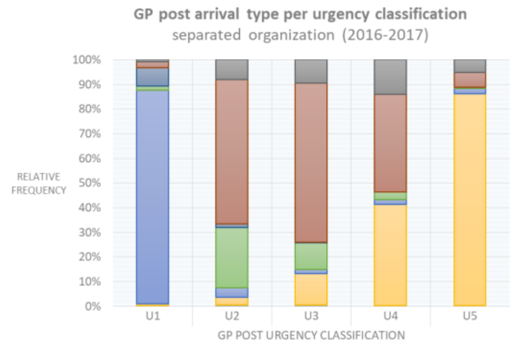
Most of this period's input variables are already discussed in chapter 5 and will remain unchanged, only the type and number of patient arrivals require some modifications.

- During the separated out-of-hours emergency care organization in between 2014 and 2015, a total of 6959 self-referrals arrived at the ED (which is equal to 12% of the total ED population). This number has dropped to zero since the integration, ED self-referrals are only allowed once the GP post is fully closed. Therefore, the number of GP post patient arrivals will be reduced during the out-of-hours emergency care, while the ED's patient arrival rates are increased by the same number. This will increase the total ED's population by (50589 * 100/88) = 57487 patients, which means that (57487-50589) = 6899 patients will be removed from the GP post, which is equal to 7.25% of the GP post's population;
- It is assumed that all additional 6899 ED self-referrals were former self-referrals at the GP post. Therefore, the GP post's patient reduction is only made for the first three A-pathway allocations including self-referrals only. A total number of 7347 self-referrals arrived at the GP post in between 2016 and 2017. Therefore, all three self-referral A-paths are reduced by (6899/7347) = 93.9%. The new A-path allocations are visualized by *Figure 29*;



	U1	U2	U3	U4	U5
A9	0,005	0,063	0,086	0,151	0,049
A8	0,052	0,573	0,660	0,454	0,067
A7	0,090	0,023	0,002	0,000	0,000
A6	0,040	0,268	0,122	0,049	0,008
A5	0,775	0,012	0,001	0,000	0,000
A4	0,021	0,038	0,093	0,325	0,865
A3	0,016	0,022	0,036	0,018	0,004
A2	0,000	0,000	0,001	0,002	0,006
A1	0,000	0,000	0,000	0,000	0,000

a) Integrated out-of-hours emergency organization (2016-2017)

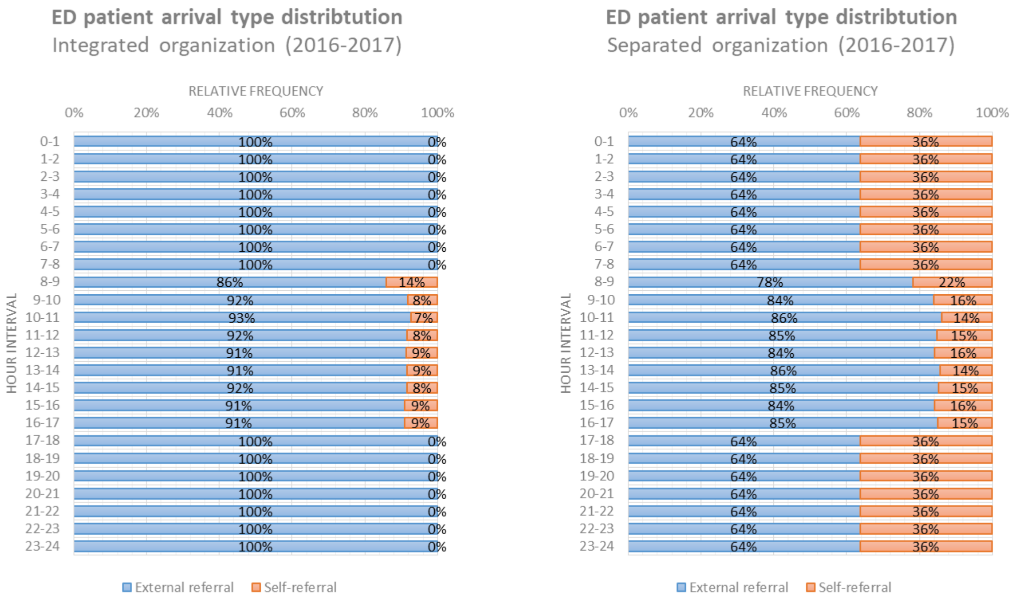


	U1	U2	U3	U4	U5
A9	0,009	0,080	0,095	0,140	0,052
A8	0,024	0,585	0,646	0,397	0,061
A7	0,075	0,015	0,001	0,000	0,000
A6	0,015	0,244	0,108	0,031	0,004
A5	0,868	0,040	0,018	0,019	0,022
A4	0,005	0,030	0,126	0,410	0,859
A3	0,001	0,004	0,006	0,003	0,001
A2	0,000	0,000	0,000	0,000	0,001
A1	0,003	0,002	0,000	0,000	0,000

b) Separated out-of-hours emergency organization (2016-2017)

Figure 100: The distribution of the care pathways into the GP post for both the separated and integrated out-of-hours emergency care. The left figure represents today's actual distribution, while the right figure represent the hypothesized distribution if the GP post and the ED would be separated without changing any other input variable.

- The X-path distributions discussed in Section 5.3.1 are used in order to determine the relative arrival frequencies for the ED's self- and external referrals. The X-path distribution should be modified to the new situation.
- It is assumed that the self-referrals are equally removed from all the GP post weekly hour intervals. This means that each hour 7.25% less patients will arrive at the GP post. On the other hand, the ED's patient arrivals will increase with 57.1% per out-of-hour interval;
- The GP post and the ED are strictly separated organization from now. Therefore, the ED triage nurses do not support the GP post with the triage of self-referrals arriving at the IEP during the night.



a) Integrated organization (2016-2017) *b) Separated organization (2016-2017)*

Figure 101: ED patient arrival distributions, excluding the GP post referrals. The left figure represents today's actual distribution, while the right figure represent the hypothesized distribution if the GP post and the ED would be separated without changing any other input variable.

Appendix W – Experimental factors

The simulation model is based on the data set corresponding to the integrated emergency organization in 2016 and 2017, including the type and number of patient arrivals, the care pathway allocations, the activity durations and the resource allocations. A total of twelve experimental factors are constructed to find an alternative configuration of the IEP Enschede. The experimental factors are clustered in three classes, corresponding to the type of organization for which the alternative configuration applies. Thirteen experimental factors are developed for both the GP post and the ED separately, but some experimental factors apply to both organizations.

GP post experimental factors:

13. Different appointment strategy
    a. Alternative slot durations;
    b. Different number of patient invitations allowed per appointment slot;
    c. Alternative priority rules given to the patient's appointment based on their urgency;
14. The allocation of a dedicated staff member for patient visits at home;
15. Alternative staff rosters for the GPs;
    a. One additional GP in the evening shift from 5:00pm to 0:00am;
    b. One less GP in the night shift from 0:00am to 8:00am.
16. Creating a patient buffer before the GP starts visiting patients at home.

ED experimental factors:

17. Alternative staff roster for:
    a. The emergency physicians;
    b. The residents of all treatment groups available at the ED;
18. The possibility to expand the emergency physicians' authorities to treat all patients;
19. The possibility to execute the triage activity in the patient's treatment room;
20. The possibility to admit patients directly into the hospital without any waiting time;
21. The possibility to access the medical specialist immediately, without any waiting time.

IEP experimental factors:

22. The possibility to share the triage results between the GP post and the ED;
23. The possibility to make use of each other's treatment rooms;
24. Different responsibilities for the triage of all self-referrals contacting the IEP Enschede.
    a. Only GP post staff execute the physical triage of self-referrals;
    b. Only ED staff execute the physical triage of self-referrals.

The motivation to include these experimental factors are given in the following subsections, including the variables' ranges. Note that most experimental factors do not include the decision to hire more staff members to increase capacity, it should be examined first if the existing capacity can be allocated more efficient and effective. The GP post and ED stakeholders indicated that it is hard to find new staff members for today's organization, an increase in capacity would be too costly.

W.1. GP post experimental factor 1a – Appointment slot durations

The GP post resulted to be quite robust, because the increase in the number of GP post arrivals did not increase the GP post LOS due to the appointment strategy implemented. The staff's utilization rates can increase by approximately 25% without resulting into an increase of the patients' waiting time at the GP post itself. However, the appointment strategy itself is built around multiple assumptions, only one patient can be scheduled every 10 minutes for example. The question arises if alternative time slot durations will result in better LOS values. All values ranging from 5:00 to 15:00 minutes are evaluated with an interval length of 1:00 minute.

W.2. GP post experimental factor 1b – Appointment patients per slot

The number of patient arrivals in one appointment slot do also affect the GP post performances, which may be interesting to reduce the GP post LOS. The number of patient arrivals allowed per time slot depend on the maximum number of patients present at the moment. Therefore, the number of patients per slot is expressed as a percentage of the GPs scheduled (50%, 75% and 100%).

W.3. GP post experimental factor 1c – Appointment urgency priority

Currently, the GP post does not schedule more patients than 50% of the number of GPs available in each time slot. However, high-urgent patients may be allocated to an additional time slot (U1 patients only). It may be interesting to see if more patients may be prioritized for early invitation. Five alternatives are evaluated, each alternative accepts one urgency classification additionally.

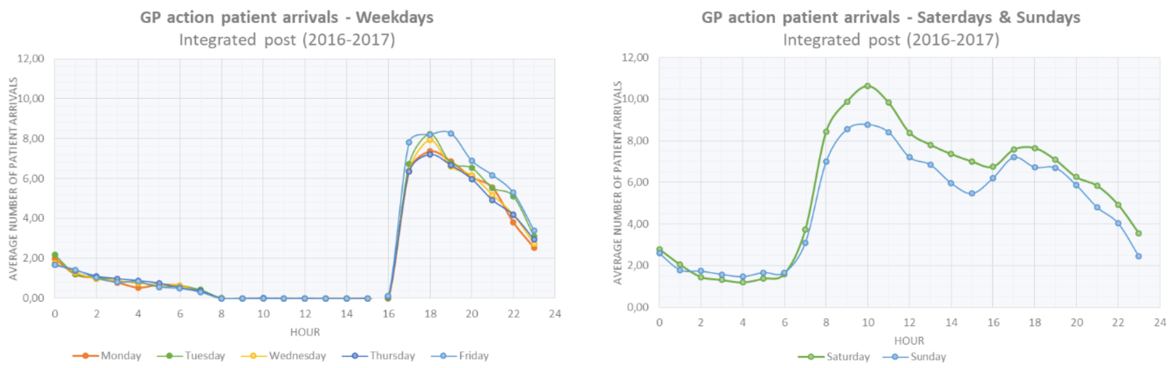
W.4. GP post experimental factor 2 – Dedicated driver

The GP post experiences an increase in activity durations, the staff members are also highly utilized. Especially the GP visits at the patients' home require relatively much resources, which reduces the staff availability at the GP post and increases the patients' waiting times. Therefore, it may be interesting to create a new staff position within the GP post who is purely dedicated to the visits at home (let's call this function the "dedicated driver"). The dedicated driver will be allocated to the patient visits at home during busy hours only. Therefore, the work roster of the dedicated driver is assumed to be equal to the coordinating assistant's roster. GPs may still be allocated to patient visits at home, but the dedicated driver is prioritized in order to make the GP available for physical consults at the GP post. The number of GP post cars remains unchanged. The experimental factor is simply represented by a Boolean variable.

The main aim of this experimental factor is to determine if the GP visits at home can be treated separately in order to make the GP post activities more flexible. The dedicated driver will represent one additional function which may be created in the near future. For example, a GP can be assigned to visit patients only, but other function descriptions are also possible. The allocation of a NP is also possible, especially because positive experiences gained during a test pilot (Giesen, et al., 2017).

W.5. GP post experimental factor 3a – GP evening staff roster

Today, two GPs are scheduled every evening and night shift, while four GPs are scheduled for the weekend shift over day. However, the number of patient arrivals during the workdays is relatively high in comparison with the staff availability (*Figure 58*). Eight patients arrive on average during the evening, while the average number of patient arrivals overday during the weekend is slightly higher. However, two GPs are scheduled for the evening while four GPs, one NP and one GP assistant for the weekend.



a) Average week arrivals *b) Average week arrivals*

Figure 102: GP post patient arrivals, requesting a type of treatment given by a GP.

Therefore, an alternative staff roster is investigated in which three GPs are hired between 5:00pm and 0:00am every day. All other hour schedules remain unchanged. Previous simulation studies also investigated the impact of alternative GP rosters (Borgman, 2013; Koster, 2014). Borgman predicted that an additional GP would result into a GP post LOS decrease of approximately 65 seconds on average in the IEP Almelo, while Koster estimated a reduction of 4.8 minutes in the IEP Enschede.

W.6. GP post experimental factor 3b – GP night staff roster

The GP post stakeholders indicate that it is hard to find additional GPs for the evening shifts. Simply increasing staff capacity is therefore not an option, but a different allocation of the staff already available is still possible. The GP post staff's utilization rate is the lowest during the nights (*Figure 58*). For example, no more than 2 patients request a GP during the night for all workdays. The same pattern is observed for the weekends, but then the arrival rate is slightly increased to a maximum of 3 patient arrivals per hour. Therefore, this experimental factor includes a modification of the GP post's night shifts for all days in the year, reducing the number of GPs present at the IEP to one. If one GP could manage to treat all patients without a strong reduction of the GP post's service levels, the implementation of other alternatives like experimental factor 2 and 3a could motivated better.

W.7. GP post experimental factor 4 – Patient buffer GP visit

Nowadays, GPs start to drive immediately after finishing their last task once the request for a patient visits arrives. Therefore, the staff allocations for patient visits at home are prioritized over the physical or telephonic consults conducted by the GPs, without taking the number of patients in the physical waiting room into account. It may be interesting to investigate if the GP visits at home could be initiated at a later point in time, allowing the GPs to reduce the workload at the GP post itself. Therefore, a buffer of waiting patients is created, which may be visited by a GP once the buffer sizes increases to a predefined threshold value which varies from one up to three waiting patients.

W.8. ED experimental factor 5 – ED staff roster

Figure 58 visualized that the number of GP requests differ per hour, the same applies for all ED staff members. The average ED staff requests per hour are visualized in Appendix R. The alternative schedules for all emergency physicians and residents are based on these arrival charts. Previous simulation studies also investigated the impact of alternative rosters for both emergency physicians and residents (Borgman, 2013). An additional surgical resident would decrease the ED LOS by 60 seconds approximately, the effect of the internal residents was just a reduction of 10 seconds.

W.9. ED experimental factor 6 – Authorized emergency physicians

The ED residents experienced workload increase due to the increased number of GP post referrals. Especially the surgery/orthopedic residents have to work hard in order to treat all patients. The high utilization rates result into longer waiting times for the anamnesis and final treatment activities. In order to reduce the workload, the emergency physicians are authorized to treat both unlabeled and labeled patients of all treatment groups. This decision will increase the available capacity without increasing the number of staff members hired. The experimental factor is simply represented by a Boolean variable. Koster (2014) also investigated the impact of changing the emergency physicians' authority, she expected that the ED LOS could be reduced by 43 minutes (-27.7%).

W.10. ED experimental factor 7 – Triage in treatment rooms

The ED stakeholders are investigating the possibility to perform the triage activity within the patient's treatment room instead of the dedicated triage room. It is expected that staff members would be allocated faster to the patient's anamnesis once the patient is allocated to the treatment room already.

The triage is not executed by a dedicated triage nurse, but all ED nurses can be allocated to the triage activity. Therefore, the intervention aim's to improve both the ED LOS and the ED's service statistics, because patients can be seen earlier in more alternative rooms.

W.11. ED experimental factor 8 – Hospital admittance

Patients have to wait before they can be admitted into the hospital, resulting in a lot of waiting time that could be avoided by close collaboration with the hospital inpatient polis. This experimental factor is represented by a Boolean variable. This experimental factor is already investigated by previous simulation studies (Borgman, 2013). Borman expected that direct hospital admittance would reduce the average ED LOS in the IEP Almelo by 5.5 minutes approximately.

W.12. ED experimental factor 9 – Medical specialists' availability

Medical specialist are not allocated directly to the ED, but residents may contact them for (telephonic) advice. However, it takes time before the medical specialist is available to help the patient's treatment. Therefore, it may be interesting to see how the LOS values are affected if the medical specialist is immediately available. This decision is represented by a Boolean variable. This experimental factor is already investigated by previous simulation studies (Borgman, 2013). Borgman added one medical specialist to the ED, which resulted into a ED LOS reduction of 2 minutes on average.

W.13. IEP experimental factor 10 – Triage collaboration

The problem identification in chapter 1 revealed that both the GP post and ED staff members experienced a lot of problem regarding the physical triage of self-referrals. Therefore, it may be interesting to investigate if the logistic performances can be improved by sharing the triage results from each other, allowing the ED to skip the triage activity if this is already performed by the GP post. The experimental factor is simply represented by a Boolean variable. Koster (2014) also investigated this experimental factor, she advised it to implement this decision in the IEP Enschede, because the ED LOS could be reduced by 6.4 minutes (-4.2%). Borgman also predicted a relative small reduction of 2 minutes.

W.14. IEP experimental factor 11 – Room sharing

Sometimes the ED is over utilized and requires more treatment rooms, while the GP post has free capacity left. Two diagnostic rooms in the GP post are hardly used in practice, while they can be adapted to the ED's requirements very easily. Therefore, it may be interesting to see what happens if both organizations can allocate patients to the diagnostic rooms. The possibility to treat GP post patients in the ED treatment rooms is not taken into consideration, because the GP post's capacity is relatively high. The experimental factor is represented by a Boolean variable. Koster (2014) also investigated the effect of using each other's rooms, which did not result into any significant result.

W.15. IEP experimental factor 12 – Triage responsibility

Currently, the ED support the GP post triage nurses with the triage of all self-referrels arriving during the night. Only one GP assistant is available during the night for telephonic triage, while the several ED nurses are present. However, the staff members identified several problems concerning the night triage activities, as discussed in the problem identification of chapter 1. Therefore, alternative responsibility allocations are investigated. First, the current type of organization is taken into account in which the ED support the triage between 11:00pm and 8:00am. Secondly, the GP post is fully responsible, while the third experiment includes full responsibility for the ED nurses. This experimental factor is represented by an integer variable.