UNIVERSITY OF GRONINGEN

MASTER RESEARCH PROJECT

DECISION MAKING ON AMBULANCE DIVERSION AT THE EMERGENCY DEPARTMENT

August 15, 2018

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Abstract

An increasing problem of the emergency department is crowding. When emergency departments get overcrowded, the quality of care can go down. Also, the safety of patients and the personnel can come into question. This overcrowding can result in a patient stop and an ambulance diversion. This means that ambulance delivered patients are not able to receive care immediately as ambulances are diverted to other hospitals. Additionally, walk- in patients do not receive immediate care as well, as they are placed in the waiting room until the emergence department is not overcrowded anymore. Literature shows several causes to overcrowding. However, research about patient flow patterns and mechanisms that can lead to ambulance diversion have not been performed yet. Therefore, a case study at the emergency department of the Medisch Centrum Leeuwarden is conducted to seek for patient flow patterns and mechanisms that can lead to the implementation of ambulance diversion. This research showed that during ambulance diversion days the emergency department is more crowded, but differences with other days are small. Also, more tests are needed for the patients which take more time and the length of stay of patients was higher. During the analyses of a set of ambulance and non-ambulance diversion days with more or less an equal distribution of the numbers of arrivals and the day of the week, it was found that the work in progress on ambulance diversion days was higher. Nonetheless, no specific patient flow patterns and mechanisms have been found that precede ambulance diversions. However, the hours before ambulance diversion are characterized by specific patient characteristics, such as more patients needing a lab request. Furthermore, the role of the coordinator seems to have an influence on ambulance diversions. Both for days with and without ambulance diversion the analysis shows that pressure on room availability at the emergency department can be largely reduced by earlier transport of patients that have already been assigned a bed in a ward.

1 Introduction

To give emergency care to patients arriving at the emergency department (ED) is the main purpose of the ED. However, in recent years, a major issue in the EDs of hospitals is overcrowding due to an increasing number of patients (Di Somma et al., 2015). During overcrowding, staff and resources cannot keep up with the demand, which can lead to lower quality of care for patients (Pines, 2007). Several other effects crowding has on patients include longer length of stay (LOS), lower patient safety and a higher mortality rate (Sprivulis et al., 2006; Trzeciak and Rivers, 2003). Additionally, crowding hinders a smooth patient flow through the ED. Flow problems can even lead to cases in which the EDs consider themselves not able to accept patients anymore.

To regulate the flow of patients during overcrowding moments and to keep the patients' health and quality of care at an acceptable level, hospitals sometimes use ambulance diversion (Patel et al., 2006). In that case, the hospital does not accept a part of the new incoming patients until the flow through the ED is controlled again. This means that ambulances will be rerouted to other hospitals and patients cannot be delivered to the ED that uses ambulance diversion (Burt and McCaig, 2006). Since nowadays ambulance diversion is a more common practice than an exception, it can be seen as a growing problem (Handel et al., 2011). Additionally, ambulance diversion is also used to decrease stress on personnel and individual departments (Geiderman et al., 2015). Due to ambulance diversion, the ED will be closed for arriving patients for a certain amount of time until the crowding of patients is controlled. Other arriving patients are placed in a waiting room or referred to other hospitals during ambulance diversion.

Causes related to ambulance diversion have been researched in several studies. These causes include (according to Burt and McCaig (2006); Fatovich et al. (2005) and Schull et al. (2003)): a lack of inpatients beds, a high number of ED patients, number of admitted patients at the ED, the complexity of ED patients, ED and hospital staffing shortage and poor inpatient flow. These studies show that multiple factors can influence the occurrence of ambulance diversion at the hospital. Nonetheless, a lot of variation occurs in the usage of ambulance diversion (Patel et al., 2006), which indicates that it differs per hospital what they perceive as the right justification to use ambulance diversion.

Ambulance diversion does not solely have effect on the ED of the hospital, but it also has an effect on the emergency medical services that control the ambulances. During ambulance diversion it takes more time for the emergency medical services to deliver patients at the ED due to rerouting to other hospitals. As an effect, not only the health and safety of the transported patients can be affected but also patients are affected who are waiting for the aid of the emergency medical services (Trzeciak and Rivers, 2003). Next to this, ambulance diversion affects EDs of the whole region due to the increasing flow at the EDs where the ambulances are diverted to (Jeanmonod and Jeanmonod, 2018). Besides these effects, another effect of ambulance diversion is the associated lost hospital revenues (McConnell et al., 2006).

The causes of ambulance diversion as well as the effects ambulance diversion has on patients' health and safety have been studied a lot. A logical correlation exists, for instance, between a higher chance to have ambulance diversions and less beds or nurses available. However, knowing these causes does not contribute to making operational decisions to prevent ambulance diversion. Preventing ambulance diversion requires answering the question which operational decisions could have been made in advance. Still little research has been done on mechanisms and patient flow patterns that can lead to ambulance diversion at the ED. By researching mechanisms and patient flow patterns, operational decisions to prevent ambulance diversion could be managed. Moreover, hospitals do not know exactly when ambulance diversion is needed, until suddenly patients' safety and quality of care comes into question. Therefore, this study aims to generate a better understanding on the occurrence and decisions before ambulance diversion. The research question that will be answered in this study is:

What are the mechanisms and patterns that lead to ambulance diversion?

Mechanisms in this study consist of antecedent matters and decisions that lead to the ambulance diversion decision. Patient flow patterns in this study are related to the throughput patterns of the patients.

This study will focus on ambulance diversion in a case study at Medisch Centrum Leeuwarden in the Netherlands. By focusing on the situations previous to ambulance diversion, characteristics and triggers leading up to ambulance diversion can be identified. The results of this study will provide new insights into patient flow patterns and mechanisms leading up to ambulance diversion at EDs. Managerial implications of this research include the awareness of these patterns and mechanisms that influence operational decisions made by medical staff to prevent ambulance diversion. Next to this, the results of this study can be used to steer the decision making policy on when to use ambulance diversion at the hospital. Furthermore, this research helps identifying possibilities for redesigning the flow at the ED. This research also contributes to existing literature by researching the occurrence of ambulance diversion and focusing on the situation leading up to this occurrence.

Section 2 provides a literature review focusing on the aspects that affect ambulance diversion. Thereafter, the case study is presented and the methodology for the specific case is defined in section 3. Then the results are presented in section 4. Finally, the main outcomes, limitations and conclusions are summarized in section 5.

2 Background

This background section reviews the currently available literature to form a basis for this study. Relevant aspects such as emergency departments characteristics, crowding and ambulance diversion are explained.

2.1 Emergency department

EDs deliver emergency care to patients who are either arriving by ambulance, referred by their general-practitioner or by self-referral. The ED delivers emergency care to patients with a broad spectrum of urgencies. Some patients need acute care due to life-threatening situations, while others have small injuries and do not require medical attention straight-away. According to Asplin et al. (2003) care provided at an ED can be divided into: emergency care, unscheduled urgent care and safety net care. Emergency care is the treatment of the injured as well as the seriously ill patient from outside the hospital. Unscheduled urgent care is care provided by the ED because other clinics inside the hospital sent patients to the ED to have a faster diagnosis. Safety net care is care provided when all other options to receive medical care are operating at their maximum and above and thus cannot help patients anymore, then the ED functions as last resort for the patients. Due to serving as a safety net, the ED should have the capacity and capability to deliver care to the patients, regardless of: patient volume, urgency, severity or resources available at the ED (Pham et al., 2006).

Whenever, a patient arrives at the ED the patient will receive a triage code to categorize the urgency of the patient. A common used system to categorize these urgencies is the Manchester triage system (Mackway-Jones et al., 2013). After triage, each patient follows a pathway which aims to provide the best care for that patient. Care coordinators, physician and nurses take care for this optimal medical pathway for the patient. The care coordinators have the responsibility to organize the patient care activities in such way that this results in the best outcome for the patient (Schultz et al., 2013). During treatment, all kinds of tests can be done to help form a diagnosis, these tests can be radiology scans, X-rays or laboratory tests. Next to these tests, specialists at the ED can also help with the diagnosis if necessary. After diagnosis, the patient can be admitted to the hospital, discharged back home or elsewhere. The care coordinator also coordinates this discharge flow.

2.2 Overcrowding

During crowding moments the available resources cannot keep up with demand which can lead to a reduction in quality of care (Pines, 2007). The causes of this inability to keep up with the demand can be found in both internal and external factors at the ED of the hospital (Di Somma et al., 2015). The unavailability of resources can be noticed in different parts of the hospital, e.g. capacity shortage at surgery, a sudden rise in input of patients at the ED and therefore not enough physicians available at that moment. According to Di Somma et al. (2015), the most relevant factors are shortage of staff (physician and nursing) and insufficient access to hospital beds.

According to Hoot and Aronsky (2008), there are three main themes in which crowding factors can be subdivided: input, throughput and output. Problematic input occurs because of patients presenting themselves at the ED without having a high triage score, 'frequent flyer' patients, and the influenza season. Problems in throughput are strongly associated with inadequate staffing

and relates to the flow of the patient at the ED. Output problems are found to be related with an insufficient number of hospital beds and patient boarding obstacles.

Overcrowding of an ED can lead to longer waiting times, increase the length of stay of the patient and possibly result in the decision to divert ambulances. Another consequence of overcrowding is that patients' safety cannot be guaranteed anymore when more patients arrive (Fatovich and Hirsch, 2003) and it is associated with patient mortality (Bernstein et al., 2009). Additionally, staff at the ED can be stressed due to overcrowding and hence cannot perform their work properly (Geiderman et al., 2015).

Solution approaches to crowding can be divided in three main themes: increased resources, operations research and demand management (Hoot and Aronsky, 2008). Increasing resources means more personnel, beds, observation units or other resources to control crowding at the ED. Operations research solutions could be found in the use of queuing theories and crowding measures. Lastly, crowding solutions can be found in demand management by controlling the inflow of patient through e.g. non-urgent referrals, destination control and ambulance diversion.

2.3 Ambulance diversion

To decrease stress and overcrowding at the ED, ambulance diversion procedures can be used, meaning that the ED will be closed for an unknown time-span (Geiderman et al., 2015). During this time-span ambulances are diverted to other hospitals and non-urgent patients arriving with their own transport are placed in the waiting room or referred to other hospitals as well. To determine the justification of ambulance diversion a protocol is used in most hospitals. Though, there exists a lot of variation in hospital practices concerning the use of ambulance diversion (Handel et al., 2011; Patel et al., 2006).

Ambulance diversion is a common but controversial method, as patient's safety can come into question. In general, it does not always result in the most desirable outcome for the patient (Geiderman et al., 2015). Besides harming the safety of the transported patient, it can also endanger others who depend on the ambulances. Because the ambulances will be rerouted to another hospital, it can take more time for the ambulances to return and treat the next patient (Trzeciak and Rivers, 2003). Using ambulance diversion to manage the flow at the ED might solve the crowding issue for one hospital, however it shifts the problem to other hospitals nearby (Jeanmonod and Jeanmonod, 2018)). Next to this, Pham et al. (2006) mention that, ambulance diversion just slightly leads to a decrease of crowding at the ED.

Research in the USA has shown that the hospital's financial state is also affected by the use of ambulance diversion, as ambulance diversion is associated with lost hospital revenues (McConnell et al., 2006). Due to diverting ambulance delivered patients to other hospitals, the hospital that uses ambulance diversion loses revenue. Especially ambulance delivered patients that are admitted to the hospital create a high revenue for the hospital (McConnell et al., 2006) and therefore if these patients are not delivered at the ED the hospital will miss even more earnings. It should be noted however that this research was country specific and might not have the same impact on hospitals outside the USA.

2.4 Causes of ambulance diversion

Burt and McCaig (2006) have done extensive research on ambulance diversion causes. By using questionnaires at EDs they came to the conclusion that the main reasons for ambulance diversion according to the staff at the hospitals are as follows: lack of inpatient beds, high number of ED patients, complexity of ED cases, hospital staffing shortage and ED staffing shortage. Furthermore, they have found a relation between hospital size, occupancy rate and time on ambulance diversion. Larger bed size of a hospital and a higher occupancy rate correspond to a longer duration of ambulance diversion. According to Fatovich et al. (2005), another factor contributing to the use of ambulance diversion is poor inpatient flow of patients.

The time of day also influences the occurrence of ambulance diversion. Schull et al. (2003) found that during evening shifts and on Mondays, the frequency of ambulance diversions peaked and also had the widest variation in duration of diversions. During the study a regression analysis was performed and it was found that there are multiple factors that contribute to the duration of ambulance diversion. According to their research the number of patients waiting to be admitted to the hospital, the number of boarded patients due to a shortage of beds and delays in assessment, the number of patients arriving by ambulance were predictors of increased duration of ambulance diversion during an ambulance diversion. Additionally, the number of patients admitted and the corresponding delay are contributors to ambulance diversion in their hospital. However, staffing of the ED was not correlated to ambulance diversion, which is in contrast with Burt and McCaig (2006), who found that staffing is a reason for ambulance diversion and crowding.

These studies, found causal insights with the use of ambulance diversion through regressions analysis and questionnaires. For instance, the relation between a high number of patients being admitted to the hospital and a lack of inpatients beds leading to ambulance diversion is rather logical. However, these insights do not contribute to make operational decisions in the hours before ambulance diversion to prevent ambulance diversion.

2.5 Implications

The fact that ambulance diversion usage has increased in recent years is a worrying fact for patient outcomes (Geiderman et al., 2015). Ambulance diversion is seen as a solution to decrease crowding at the ED in most studies (Patel et al., 2006). However, it decreases the flow of patients at the ED just slightly (Pham et al., 2006). Additionally, literature has focused on crowding and using ambulance diversion as a substitute for crowding (Pham et al., 2006), which is contradicting to seeing ambulance diversion as a solution as mentioned by (Patel et al., 2006). Next to this, several studies focused on causes of ambulance diversion and found that the occurrence of ambulance diversion could be due to different factors (Burt and McCaig, 2006; Fatovich et al., 2005) and (Schull et al., 2003). These studies focused on relations between factors and causes contributing to ambulance diversion. However, these causes and factors do not clarify operational decisions preceding ambulance diversion, such that ambulance diversion can be prevented. Moreover, these studies do not clarify which patient flow patterns and mechanisms precede ambulance diversion. Having better insights on patient flow patterns and mechanisms that lead to ambulance diversion helps understanding the occurrence of ambulance diversion. Therefore, this thesis will focus on examining patient flow patterns and mechanism that can lead to the occurrence of ambulance diversion based on patient data.

3 Methodology

The aim of this study is to determine the mechanisms and patient flow patterns that can lead to ambulance diversion by analyzing periods of time preceding ambulance diversion. A case study approach is used to analyze these mechanisms and patterns. This section describes the research context, the ED of the case hospital, the data and data analyses. The approach of the data analysis will consist of analyses that uses data over time, such that patient flow patterns and mechanisms will become visible. An explorative analysis is made to clarify and localize the occurrence of ambulance diversions. Subsequently, patient throughput analyses are performed. Thereafter, the system state of the hours before ambulance diversion is analyzed to determine mechanisms that precede ambulance diversion. Finally, observations and a qualitative analysis clarify the operations at the ED and problems of the staff.

3.1 Research context & case description

From 2010 till 2015 the patients that visited the ED in the Netherlands has been doubled up to 2 million (van Aartsen, 2017). Therefore, the hospitals alarmed the government about the overcrowding problem and the pressure on the nurses and doctors at the ED (van Steenbergen, 2016). Next to this, evidence shows that nowadays patients encounter a longer LOS compared to a few years ago, which indicates crowding problems. Additionally, more crowding can occur due to planned changes in the organization of emergency care in the Netherlands (Van Der Linden et al., 2013).

One of the EDs in the Netherlands is located in the Medisch Centrum Leeuwarden (MCL). The MCL is chosen as a case for this study about ambulance diversion due to the high frequency of ambulance diversions that occurred at the MCL. Additionally, the size of the hospital, and the unknown causes preceding an ambulance diversion make it a good choice as a case hospital. Additionally, by doing a case-study the complexity and nature of the phenomena can be researched (Voss et al., 2002). The choice for a case study is relevant, since this strategy can indicate a causal relationship between different variables, as explained by (Mills et al., 2009).

This study is executed at the ED of the MCL in Leeuwarden, a city in the northern part of the Netherlands. The ED contains 29 rooms including 24 treatment rooms, one plaster room, one stitch room, two triage rooms and one specialist unit room (see figure 1). These 24 treatment rooms are divided in three parts: High complex care (4 rooms), medium complex care (7 rooms) and low complex care (13 rooms) [1]. The ED cannot utilize all available rooms due to capacity problems in terms of the number of nurses available. Hence, several rooms are closed and less patients can be treated in parallel than the ED was designed for. On average there are approximately 17 rooms available in the new ED to treat patients in parallel. The rooms open in the new ED are approximately the same number of rooms that were open in the previous ED. The high complex care rooms of the new ED are all open to treat the high complex patients.

Patients can arrive at the ED in different ways. They can be self-referrals, presented after consultation of the general practitioner or they are brought in by ambulance. The blue dashed arrow in figure 1 shows an ambulance delivered patient. This patient will be placed in a room where the diagnosis and treatment will be performed. After the diagnosis and treatment the patient

[1] The old ED consisted of 16 treatment rooms of which 2 were high complex care rooms.

can be discharged to the hospital (orange dashed line) or discharged to home (red dashed line). When patients arrive in the ED they will firstly be triaged by a triage nurse. This can be done in the triage room or in the room where the patient is placed if the patients arrive by ambulance. The nurses can quickly assess the urgency and they check for allergies, current medications, vital signs, obtain height and weight, perform diagnostic tasks as drawing blood and perform an electrocardiogram. The physicians assess the medical problem and start the treatment. The physicians have the responsibility to stabilize and treat all patients in need of urgent medical care. When a patient arrives in a critical state, the physician will be available to directly provide care to the patient. Nevertheless, they also have the responsibility to treat the less-urgent patients. At the MCL triage codes are used to determine the proper triage per patient, in table 1 the triage codes as used by the MCL can be seen.

During every shift there is one physician coordinator and one nurse coordinator who are responsible for the flow and care of patients. The nurse coordinator assigns rooms and nurses to the patients, and also coordinates the discharge of patients to different wards in the hospital. The physician coordinator coordinates all care that is provided by other physicians at the ED. The physician and nurse coordinators also control the flow regarding (over)crowding of patients. These coordinators can apply the use of ambulance diversion if this is needed according to them. There is a deliberation between the personnel to determine if ambulance diversion is necessary at that moment or that some patients will soon leave the ED and thus ambulance diversion is not needed. Next to this, if ambulance diversion is needed the Centrale Post Ambulance is also informed that the ED of the MCL is closed until the crowding is controlled again.

Most of the time one or more ED residents are working alongside ED staff physicians in the ED, except for night hours (23.00-8.00). Also for many specialties, including internal medicine, geriatrics (Monday to Friday), cardiology, neurology, pulmonary, surgery and plastic surgery, at least one resident is available to see patients in the ED, who is being supervised by a physician, which may be an ED doctor. The orthopedics specialty is only Tuesdays every week and one weekend a month on duty, surgery covers this specialty the rest of the days. The residents might not be continuously present in the ED, but are called in when they are needed. They contact their supervisors for advice and approval mostly via telephone. Extra doctors can be called in from a specialty department to the ED when it is extremely busy.

To treat the patients, the ED is dependent on the different specialties and the other departments at the hospital. As patients follow different pathways, they also need different tests and scans for their diagnosis. Therefore, the ED can send samples to the laboratory and will receive the results after a while. Next to his, radiology request for different test are made. X-rays can be executed within the ED but MRI-scans and CT-scans need to be executed at the radiology department.

Other staff that is present at the ED includes a pharmacist assistant, who consults all patients that will be admitted to the hospital regarding their medicines. Furthermore, there are facility services employees that perform all kinds of supporting tasks, such as cleaning rooms, bringing food to patients or taking them to different hospital facilities.

Triage code	Explanation
U0	resuscitation
U1	immediate
U2	Very urgent
U3	Urgent
U4	Standard
U5	Non urgent

Table 1: Triage codes Medisch centrum Leeuwarden

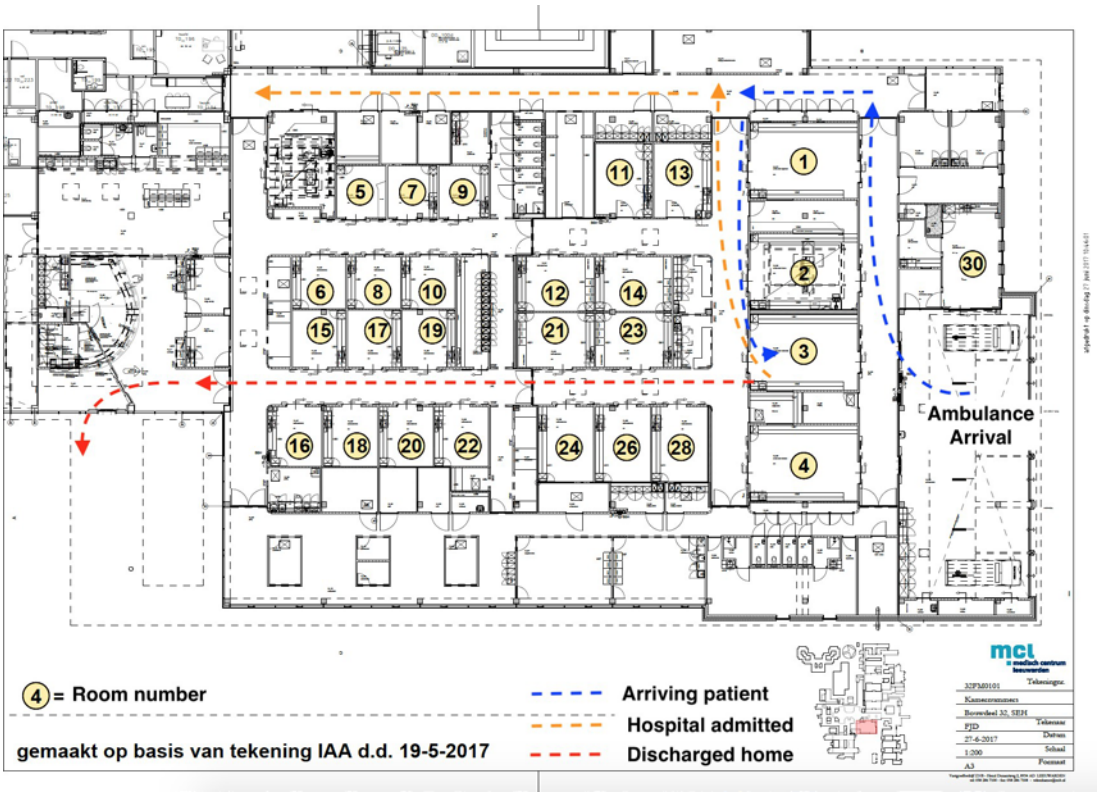

Figure 1: Map of the emergency department of MCL

3.2 Data

The aim of this study is to determine the mechanisms and flow patterns leading to ambulance diversion. Recent studies in the Netherlands have taken a novel dynamic perspective on crowding in hospitals, showing how crowding problems evolve over time (ten Have, 2016; Ter Avest et al., 2018). These studies have focused on days when crowding occurs. The approach that has been used for these crowding studies is used in this study to determine the patterns and mechanisms that lead to ambulance diversion. To perform this kind of study patient flow data from the MCL is needed.

3.2.1 Data collection

The quantitative data for this study is extracted from the EPIC software that the ED of the MCL uses for their patients records. This software collects all information regarding the patients and care they receive. Physicians and nurses register every step that the patient takes in the ED at different moments during the treatment. In Figure 2, the data points regarding the treatment and throughput of the patient can be seen.

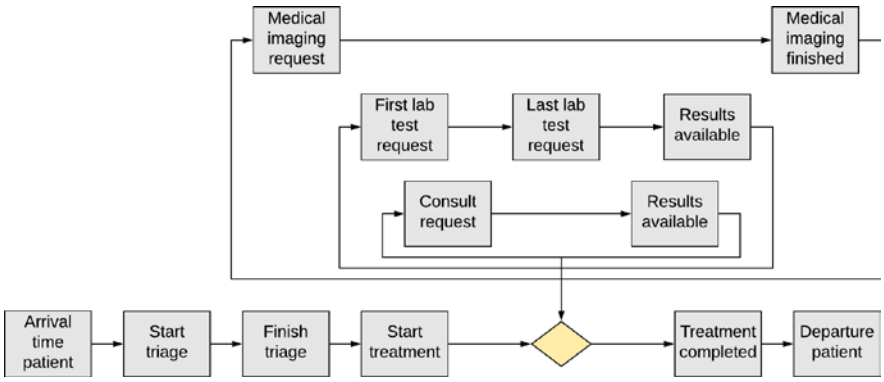

Figure 2: EPIC data collecting point

It starts with the arrival of a patient at the ED. Then the patient will be triaged by the nurses to assess the urgency. The diagnosis and treatment starts by a physician after this triage. During the treatment the patient can follow various pathways until the correct diagnosis has been made. The decisions made during this pathway will be collected within EPIC. These decisions can be lab test requests, medical imaging requests and many others. Time-stamps collected in EPIC and time-stamps of ambulance diversion will be linked with each other to search for patterns.

The data collected from EPIC that will be used for this study is summarized in table 2. There will be no patient treatment details collected and the patient data will be anonymized. From this data the input, throughput, output and ambulance diversion patterns will be analyzed. The data will cover time related data and event related data regarding the patients and ambulance diversion. The MCL recently built a new ED with more rooms, and has been using this ED since October 2017. At this new ED, approximately the same number of ED rooms have been used due to problems as mentioned in section 3.1.

Time related data	Event related data
Expected time of arrival	Patient arrival type (Self-referral, consultation, ambulance)
Arrival time at ED	Specialty assigned
Start triage time	NTS triage code
End triage time	Treating nurse
Time first consult physician	Treating physician
Time of first laboratory request	ED room assignment (At arrival)
Time of last laboratory request	Request for laboratory diagnostics [y/n]
Time first lab results available	Request for Radiology diagnostics [y/n] (Distinction between kind of medical imaging request)
Time last lab results available	Discharge way
Time of radiology request (Distinction between kind of medical imaging request)	
Time of radiology results available (No distinction between kind of medical imaging results)	
Time inpatient bed requested	
Time inpatient bed assigned	
Time patient leaving the ED	

Table 2: Data collected for each arriving patient

3.2.2 Data analysis

The analysis will follow roughly the same approach as taken by Mulder (2017); ten Have (2016) and Ter Avest et al. (2018). This analysis approach compares cumulative in- and outflow data on a daily basis, to show how crowding problems underlying ambulance diversion emerge over time. Hereby, data of arriving patients will be compared with e.g. the time preceding ambulance diversion and when it starts, or the way patients are arriving at the ED (e.g. ambulance, self-referral and referral by GP). This approach to unveil crowding problems and the association with ambulance diversions in the ED will use the same sort of throughput diagrams as (Mulder, 2017; ten Have, 2016) and Ter Avest et al. (2018). Another graphical representation that might help to study the ambulance diversions are boxplots as elaborated by Figure 4.2 of (ten Have, 2016). By analyzing periods of time preceding ambulance diversion with these approaches, patient flow patterns and mechanisms that lead to ambulance diversion can be found.

Before analyzing the data, the distinction between ambulance and non-ambulance diversion days must be clarified. The data from ambulance diversion days are retrieved from the MCL's and Central Post Ambulances' databases. This data consists of the day and the hour the diversion was reported. Based on this date and time, data will be extracted from the patient data provided by the MCL. The time span of the total dataset is from 1 April 2016 to 1 April 2018 (52,779 patients). Based on checks with experts of the MCL we decided that, patients having a longer LOS of 500 or lower than 0 minutes are removed from the data-set as they are supposed to be incorrect recorded (102 patients). Additionally, a qualitative analysis of ambulance diversions at the MCL's ED, which was executed by an internal consultant at the MCL, is also used as a data

source (Pietersma, 2018). For the analysis, the difference between the new and old ED, will be neglected due to complications as described in section 3.1.

There were 174 ambulance diversion episodes during the period covered by the data-set. The mean duration of an ambulance diversion episode was 115 minutes, ranging from 20 to 900 minutes. The average number of patients at the ED at the start of an ambulance diversion was 16 patients (range 1-27). The large range of the duration of ambulance diversion episodes and the number of patients is due to the fact that during some ambulance diversion episodes there was a power outage or a system update. However, from the data retrieved from the MCL and Central Post Ambulances it cannot be clarified which days encountered these power outages and/or system updates. These 174 ambulance diversion episodes occurred during 162 days as 12 days had double diversion episodes.

To give an answer to the aim of this research the following analysis approach is used. At first an explorative analysis is made, to determine the frequency occurrence of ambulance diversion based on the day and hour. This analysis is performed to localize the occurrence of ambulance diversion. Thereafter, the ambulance and non-ambulance diversion days will be compared for the number of arrivals, LOS, triage distribution, type of arrival and specialism of the patient. These analyses are executed to determine what the characteristics of ambulance diversion days are. Next to this, it is used to determine if there are any striking differences between the patients on days with and without ambulance diversion. If there are striking differences visible, then this can be used as guidance for further analysis during this research.

After the explorative analysis, a comparison analysis based on throughput diagrams will provide an overview of the arriving and departing patients at the ED over time. First, throughput diagrams per day are analyzed to determine if certain salient patterns can be found in the arrivals or departures of the patients on ambulance and non-ambulance diversion days. Thereafter, the average inflow and outflow related to arriving and departing patients on ambulance and non-ambulance diversion days will be investigated by using throughput diagrams. The average arrival and departure patterns are used to determine if certain patterns that cannot be seen in a day by day analysis will be seen with an average pattern. Next to displaying the arriving and departing patients, the work in progress (WIP) and projected LOS can be extracted from throughput diagrams. The WIP is calculated by measuring the vertical distance between the arriving and departing patients, the projected LOS is calculated by measuring the horizontal distance between the arriving and departing patients. By examining the throughput, WIP and LOS the flow behaviour of ambulance and non-ambulance diversion days can be seen.

Additionally, days with and without ambulance diversion with approximately the same number of patients will be analyzed by means of throughput diagrams. This is done to see if there is a more distinguished pattern when the ambulance diversion days are compared with a "control" period of rather similar non-ambulance diversion days.

Thereafter, the system state of the ED hours before ambulance diversion will be analyzed. This system state will be compared with the system state of non-ambulance diversion days during the same hours. This analysis is executed to determine if there are certain mechanisms before the occurrence of ambulance diversion. To compare the system state of ambulance and non-ambulance diversion days different factors contributing to the arrival, discharge, the WIP and LOS of the

patients will be analyzed. Therefore, radiology requests, lab request, number of available nurses, type of arrival and discharge way will be examined more thoroughly.

Next to these quantitative analyses, a qualitative analysis report of the MCL and field notes made during observations are used. The qualitative data report of Pietersma (2018) elaborates problems of the staff at the MCL's ED preceding and during ambulance diversions. The results of this report are based on interviews with the staff at the ED. This report helps to clarify the occurrence of ambulance diversions at the MCL. Next to this, observations at the MCL are used to clarify the operations of the ED. Additionally, the observations are also executed to determine the behavioral differences of the staff between busy and non-busy days. During these observations, there is a focus on the coordinators of the ED to check how they behave during different crowding moments at the ED. The qualitative data from the MCL is used to confirm the finding of the data analysis and the observations.

4 Results

This section presents the results obtained from analysis of the quantitative data, the qualitative data and the observations. Firstly, the characteristics of ambulance diversion days are determined and compared with non-ambulance diversion days. Secondly, in- and outflow patterns and throughput diagrams are analyzed to seek for patterns. Thirdly, a "control group" is used for a comparison analysis of the patterns and system state of ambulance and non-ambulance diversion days. Fourthly, an analysis is done to determine the impact admitted patients have on the WIP. Finally, the observations and qualitative data are used to determine the human factors that influence the request of ambulance diversions.

4.1 Ambulance diversion characteristics

Table 3 shows the average number of arriving patients and the average LOS during days with and without ambulance diversion. Table 3 shows that, on average more patients arrive at the ED on ambulance diversion days as opposed to non-ambulance diversion days and patients have a longer LOS.

	Average # arriving patients per day	**Average LOS (minutes)**
No ambulance diversion day	70.73	160.29
Ambulance diversion day	76.89	166.08

Table 3: Volume of patients and LOS

Figure 3 shows the distribution of the number of arriving patients per day as a box plot. The coloured part give the 25% and 75% quartiles of the distribution. The horizontal dash shows the average and the minimum and maximum values observed are the endpoints of the vertical lines. This figure shows a strong variation between days. For example, on Mondays without ambulance diversion the arrivals varied between 57 and 102 patients. However the interquartile range is only 13 patients. Figure 3 shows as well that in general there are more patients attending the ED during weekdays than during the weekend. Additionally, on Monday and Friday most patients arrive during ambulance diversion and non-ambulance diversion days. This is recognized by the ED-personnel.

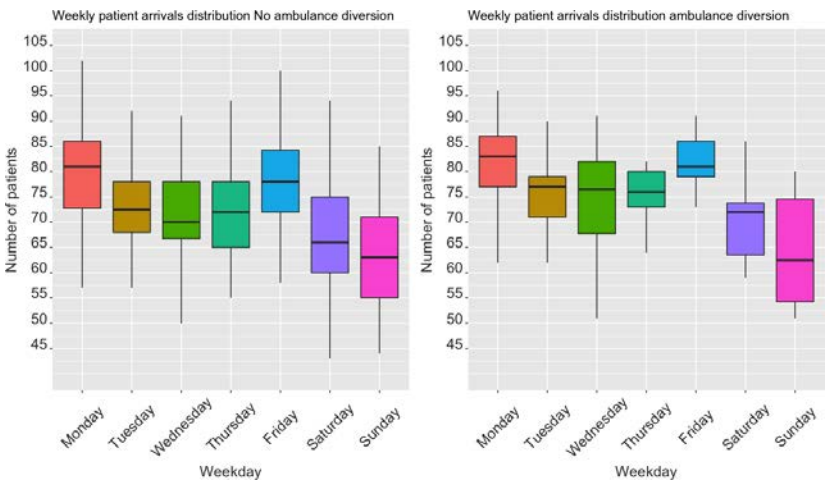

Figure 3: Pattern of arriving patients per day

To gain insight into the occurrence of ambulance diversion, frequency plots have been made based on the day (figure 4) and the hour (figure 5) at which ambulance diversion occurred. In figure 5 the 10:00 specifies the ambulance diversions between 10:00 and 10:59 etc. The figures show that the majority of ambulance diversions took place on Mondays, Wednesdays, and Fridays and between 12:00 and 16:00. A correlation can be seen between the busiest days in figure 3 and the day at which ambulance diversion is requested in figure 4. This suggests that the chance of requesting ambulance diversion is higher on busier days.

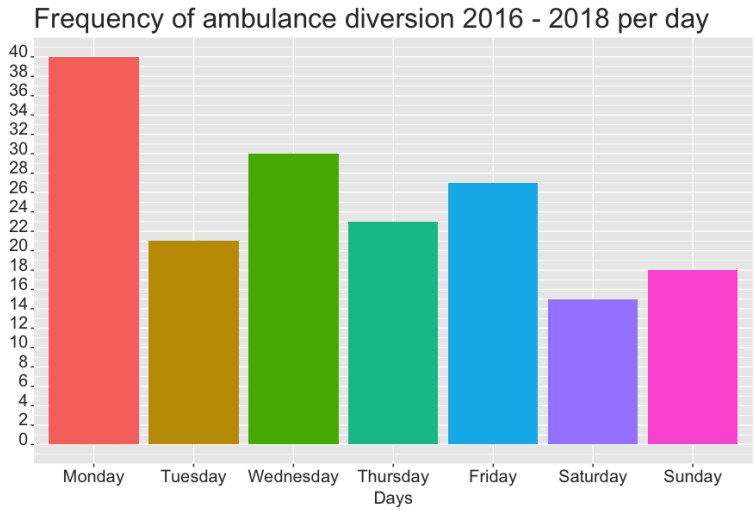

Figure 4: Frequency distribution of ambulance diversion per day

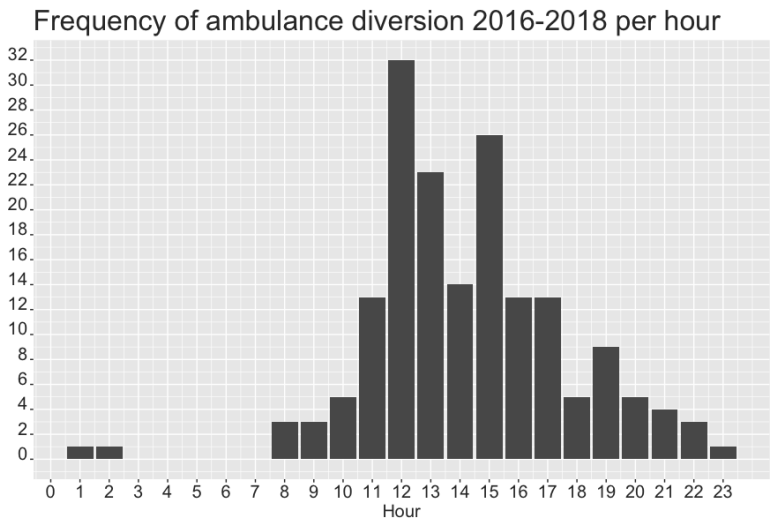

Figure 5: Frequency distribution of ambulance diversion per hour

4.1.1 Triage, Arrival type and specialism

A comparison has been made using the triage code, arrival type and specialism by which the patients are treated. This is done to determine patient characteristics during ambulance and non-ambulance diversion days. The comparison is based on the following sets of patients: (1) all patients arriving at non- ambulance diversion days, (2) all patients arriving at ambulance diversion days, and (3) patients arriving 3 hours before an ambulance diversion on ambulance diversion days. Table 4 summarizes the comparison for the three characteristics triage code, arrival type and specialism. For each set of patients table 4 shows the share of patients having a certain characteristic and the Length of Stay (LOS; in minutes) for this subset of patients.

The triage code comparison in table 4 shows that in relative terms more patients arrive with U2 complexity in sets 2 and 3, i.e. in case of ambulance diversion. As patients with a higher triage code generally need more care, this is an important insight. Additionally, the LOS on ambulance diversion days is higher compared to non-ambulance diversion days, which complies with table 3. This applies the strongest to the patients arriving in the three hours before ambulance diversion, as could be expected.

The arrival type in table 4 shows the two arrival types by which most of the patients arrive at the hospital. The other arrival types can be found in table 6 in appendix A.1. It appears that the percentage of patients arriving by their own transport is a bit higher for case 2 and 3. However, due to the triage code differences mentioned before, it was expected that more patients would arrive by ambulance, as complex patients arrive more often by ambulance at the ED.

The three specialisms, which treat the most patients are also shown in table 4. As can be seen, the specialism by which patients are treated differs only marginally between the cases. This holds for all other specialisms as well. Table 7 in appendix A.1 shows all specialisms.

	(1) No ambulance diversion		**(2) Ambulance diversion**		**(3) 3 hours before ambulance diversion**	
Triage code	Share	LOS	Share	LOS	Share	LOS
U0	0.30 %	135	0.24%	161	0.30%	166
U1	10.52 %	166	10.98%	170	9.11%	173
U2	33.76 %	180	34.61%	184	35.75%	195
U3	34.09%	155	33.77%	163	34.19%	171
U4	4.31%	144	3.97%	150	4.46%	165
U5	12.31%	135	11.39%	143	11.21%	154
Arrival type						
Ambulance	32.48%	181	32.75%	184	31.26%	199
Own transport	42.60%	148	43.04%	155	45.33%	164
Specialism						
Cardiology	16.65%	159	17.53%	162	17.29%	165
Surgery	31.43%	145	30.13%	151	30.26%	160
Internal medicine	14.19%	199	14.86%	204	14.43%	216

Note: As not all patients received a triage level, these percentages do not add up to 100%

Table 4: Characteristics of ambulance diversion and non-ambulance diversion days

The boxplots in figure 3 have shown that a strong variation occurs within the number of arriving patients at the ED per day. However, the distribution of the patients according to their type of arrival, specialism and triage code do not differ a lot on average. Though, the LOS is on ambulance diversion days higher than on non-ambulance diversion days.

4.1.2 Patients flow patterns

Figure 6 illustrates the in- and outflow of patients on ambulance diversion and non-ambulance diversion days. The x-axis shows the hour of the day. The blue curves show the inflow of patients per hour and the orange curves show the outflow of patients per hour. Additionally, the dashed curves show averages for ambulance diversion days and the solid curves show the non-ambulance diversion days.

Figure 6 shows that, ambulance diversion days have a higher average rate of patients arriving per hour from 10:00 until 18:00 compared to the non-ambulance diversion days. The in- and outflow curves in figure 6 show similarities on ambulance and non-ambulance diversion days. Both in- and outflow rates follow the same trend. However, on ambulance diversion days the in- and outflow rate is higher.

When the outflow rate would follow the inflow rate according to the average LOS the "desired" outflow would be created. The desired outflow rate of non-ambulance diversion days is 160 minutes after the inflow rate and for ambulance diversion days this is 166 minutes. When the outflow rate cannot keep up with the inflow rate, the WIP will be higher and crowding can occur at the ED. For patients arriving between 8:00 and 9:00 the horizontal distance is approximately 2 hours for both ambulance diversion and non-ambulance diversion days At 10:00 this distance has already increased to approximately 3.5 hours on days with and without ambulance diversion. It takes already 3.5 hours to get patients out at the same rate as the inflow rate at 10:00. Thus, there occurs a delay in the outflow rate at the beginning of the day. This delay results in a higher WIP and crowding at the ED.

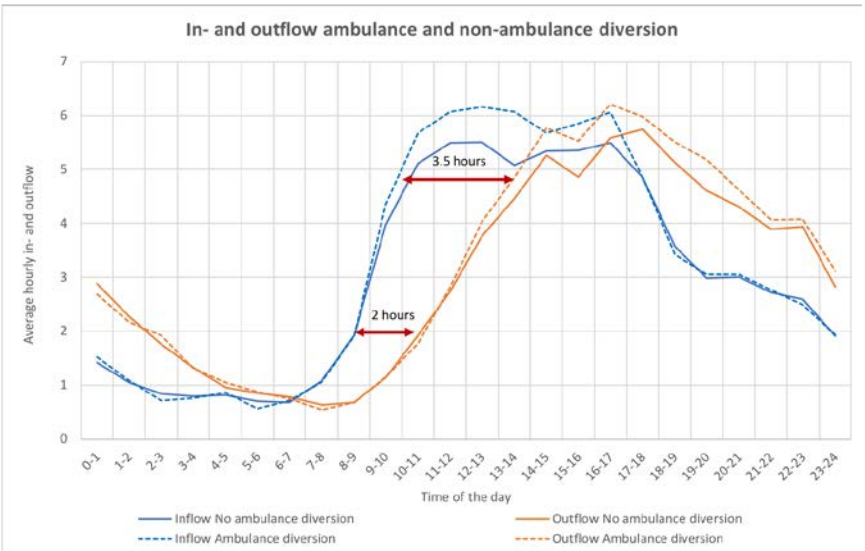

Figure 6: In- and outflow rate diagram of ambulance and non-ambulance diversion days

Figure 7 shows the cumulative numbers of arriving and leaving patients averaged for days with and without ambulance diversion in a so-called throughput diagram. The dashed curves depict ambulance diversion days and the solid curves depict non-ambulance diversion days. The arrival curves start above zero due to the fact that some patients that arrived before midnight at the ED are not discharged yet before midnight and their departure from the ED occurs on the next day. As can be seen the total number of patients arriving on ambulance diversion days is higher compared to non-ambulance diversion days. Until 10:00 the number of patients arriving is almost the same, but after 10:00 the cumulative number of arrivals is higher. This complies with the findings related to figure 6.

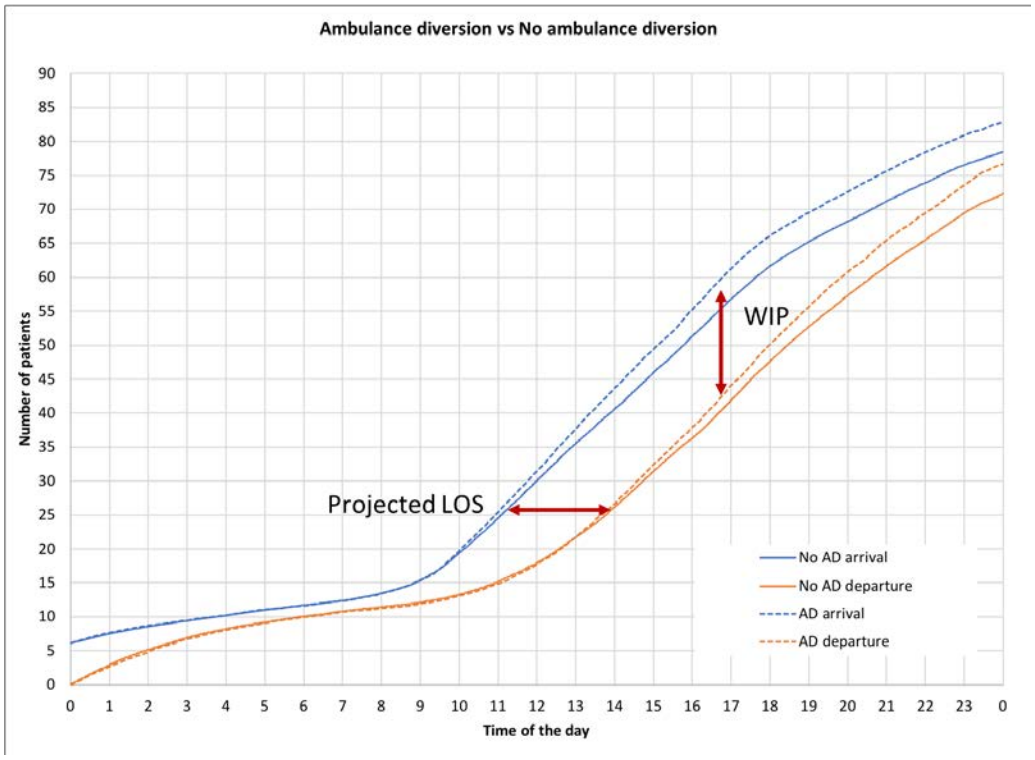

Figure 7: Average throughput diagram ambulance and non-ambulance diversion days

4.1.3 Work in progress and length of stay

A clearer overview of the differences between ambulance and non-ambulance diversion days can be seen from the WIP and LOS throughout the day. This WIP and LOS are calculated from figure 7. The average WIP is the vertical distance between the arrival and departure curves. The projected LOS is calculated by measuring the horizontal distance between the curves. This is indicated as the projected LOS as it indicates the difference between the times of the nth patient arriving and the nth patient leaving, which do not necessarily relate to the same patient. However it does indicate the LOS an average patient might expect at a certain point in time. Figure 8 shows the WIP and projected LOS, as derived from figure 7, for all days with and without ambulance diversion. The x-axis shows the time of the day, the primary y-axis shows the number of patients corresponding to the WIP and the secondary y-axis shows the LOS in hours and minutes.

As the average number of arriving patients is higher on ambulance diversion days, it could be expected that the projected LOS is higher as well, which is confirmed by figure 8. However,

large numerical differences cannot be seen. The maximum projected LOS difference between ambulance and non-ambulance diversion is approximately 10 minutes. The projected LOS fluctuates throughout the day. This is due to all kinds of different factors, such as WIP, number of physicians or nurses available, lunch time of the personnel, handovers etc..

WIP curves show the average number of patients at the ED or waiting room. Figure 8 shows that, the WIP on ambulance diversion days is higher from 10:00 until midnight. At maximum the WIP on ambulance diversion days is approximately 2.5 patients higher than on non-ambulance diversion days. The pattern that can be seen in this figure can be related to the pattern from figure 6. When the inflow rate of figure 6 is above the outflow rate, the WIP of figure 8 will increase. The WIP decreases again when the inflow rate is below the outflow rate.

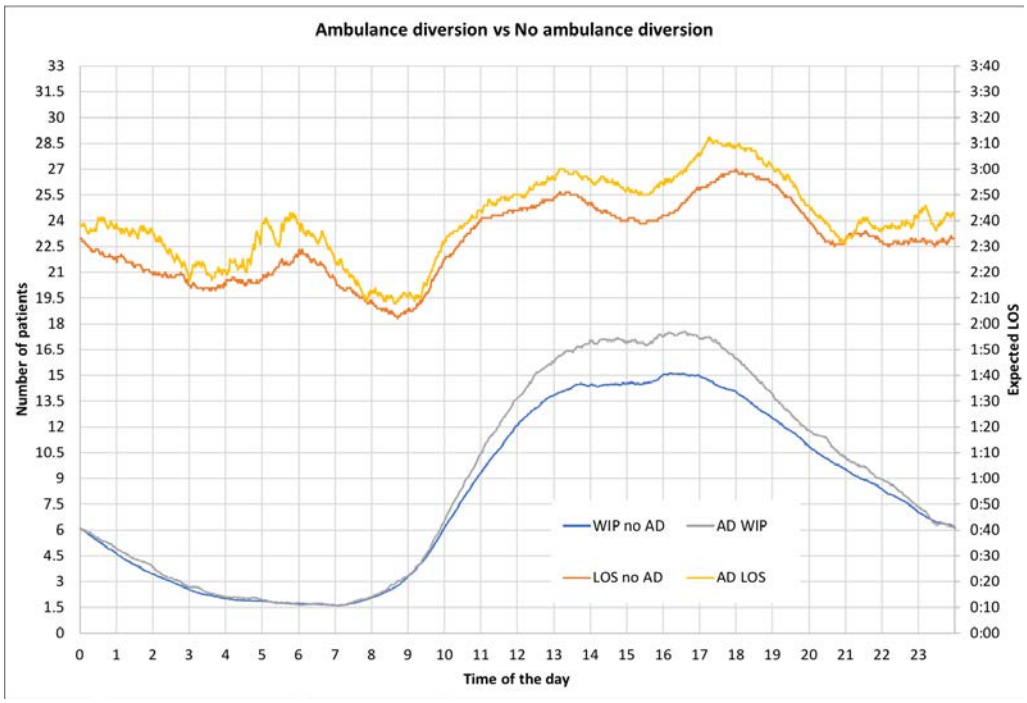

Figure 8: WIP and LOS of ambulance and non-ambulance diversion days

The figures have now revealed three general insights relevant for ambulance diversion days: (1) a higher WIP, (2) a small difference in LOS and (3) more patients arrived. Apart from these insights, no large differences between the patterns at ambulance and non-ambulance diversion days have been found.

Next to these insights it became evident from a day-by-day analysis that the ED of the MCL can cope with almost twice as much patients in WIP than treatments rooms are available on some days. Also from this analysis, no clear distinct pattern was visible between ambulance and non-ambulance diversion days. An example of this analysis for individual days can be found in appendix A.2.

4.2 Correcting for quiet days

The set of non-ambulance diversion days obviously contains more quiet days compared to ambulance diversion days. Therefore, a set of more similar days is selected as a "control group" to account for these quiet non-ambulance diversion days. We want to see the difference between ambulance diversion and non-ambulance diversion days for days that could be qualified as equally busy. The set of days with ambulance diversion is now restricted to those days at which the diversion occurred between 12:00 and 14:00. For every individual ambulance diversion day between 12:00 and 14:00, a non-ambulance diversion day with similar characteristics in terms of same number of arrivals and on the same weekday was sought for, such that pairs could be formed. Therefore, the selected set of days in the control group of non-ambulance diversion has more or less an equal distribution for the number of arrivals and the day of the week. The time frame 12:00 and 14:00 is chosen to focus on a more specific time period preceding the diversions, while still covering a large part of the ambulance diversions. The sets of ambulance and non- ambulance diversion days are comparable in terms of mix of days of the week and in the total number of arriving patients. An overview of these sets can be found in appendix A.3.

4.2.1 Patient flow patterns

The in- and outflow patterns for these more comparable sets are shown in figure 9. From these patterns it can be seen that the inflow rates of ambulance and non-ambulance diversion days are fairly similar to each other. However, at noon a higher peak in arrival rates occurs during ambulance diversion days, while the inflow rate of non-ambulance diversion is more stable.

Between 14:00 and 15:00 the outflow rate of ambulance diversion days is temporarily above the inflow rate, which does decrease a little. This peak could be due to the stop of ambulance diversion and thus more patients can leave the ED as they were treated during the ambulance diversion. The inflow rate peak of ambulance diversion between 15:00 and 16:00 could be due to the number of patients that are admitted to the ED after waiting in waiting room during the ambulance diversion. Interesting is the fact that the required outflow rate of non-ambulance diversion days stagnates slightly between 12:00 and 15:00 which increases the backlog.

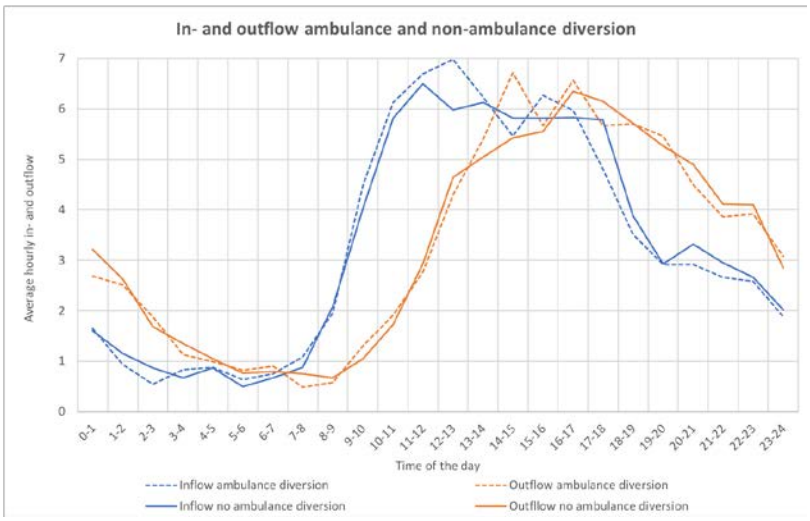

Figure 9: In- and outflow rates of ambulance and non-ambulance diversion days correcting for quiet days

Figure 10 shows the arrival and departure pattern. Due to the selection of days with a similar distribution of arrivals the cumulative numbers at the end of the day are the same. This figure shows that the arrival pattern and departure patterns of ambulance and non-ambulance diversion days also do not differ a lot. The patterns follow almost the same trend throughout the day. As can be seen from the arrival curves there are less patients arriving on ambulance diversion days compared to non-ambulance diversion days until 10:00. However, at 12:30 slightly more patients arrived, which complies with the findings from figure 9.

Next to this, it was expected that the ambulance diversion departures would have some delay (having more departures later in the morning) due to the slightly larger horizontal differences between the inflow and outflow rate of ambulance diversion as opposed to non-ambulance diversion until 12:00. From 12:00 and onwards, it was expected that non-ambulance diversion days would have a larger delay due to the stagnation in the outflow rate. However, it seems for both curves in figure 10 that there is almost no delay visible. This means that the WIP of both classifications will be almost similar to each other.

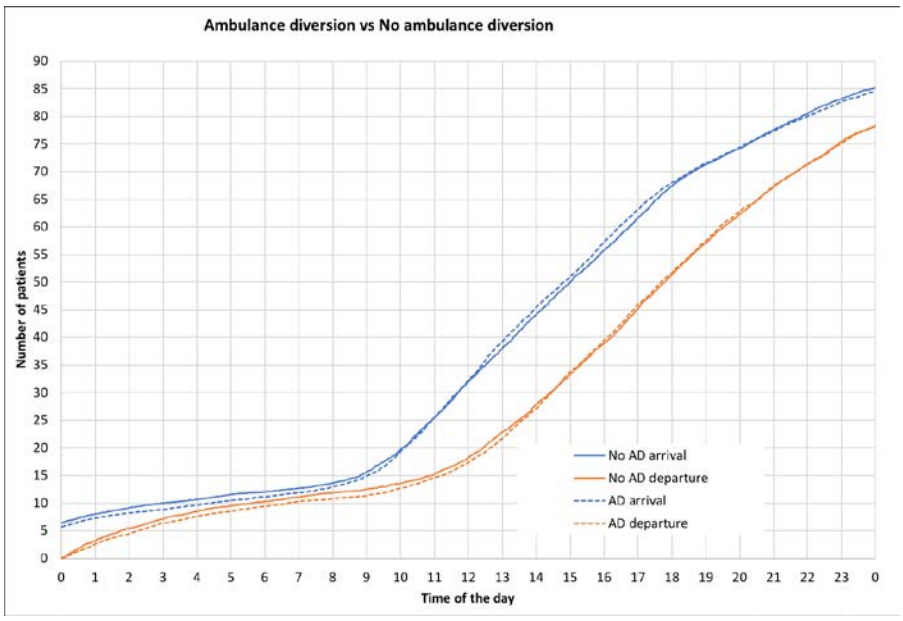

Figure 10: Average throughput diagram ambulance and non-ambulance diversion

4.2.2 Work in progress and length of stay

Figure 11 shows that during ambulance diversion days a higher WIP occurs around 12:00 and onwards. This higher WIP between ambulance and non-ambulance diversion days (with ambulance diversion occurring between 12:00 and 14:00) shows a maximum difference of 2 patients. This is interesting as a set of days is selected with the same number of patients arriving throughout the day for ambulance and non-ambulance diversion days.

The higher WIP could occur due to the slightly higher arrival rate as mentioned before. As a result the LOS during ambulance diversion days is also a little higher, as there are more patients at the ED that need to be treated. However, the patterns and WIP levels do not show large differences.

Another important insight is that the WIP of the ambulance diversion days is slightly above the number of rooms available at the ED of the MCL. This could indicate that the ED is above the maximum capacity during ambulance diversion days. A reason for this could be that the resources available at the emergency department are insufficient. Another reason could be that not many patients are placed in the waiting room to make room for patients with higher urgencies, due to the fact that placing patients in the waiting room is not a common thing to do at the MCL (Pietersma, 2018). However, it was not possible to analyze this as the data available was not sufficient enough.

Additional throughput analyses, for example based on days with the same amount of arriving patients and approximately the same WIP at 12:00 can be found in appendix A.4. These analyses, show that on ambulance diversion days also a higher WIP can be found, though the number of arriving patients is equal for ambulance and non-ambulance diversion days.

Next to the higher arrival rate, other factors could also lead to this higher WIP and LOS. Therefore, a more complete picture of the system state in the hours before ambulance diversion must be created, which will be done in the next subsection.

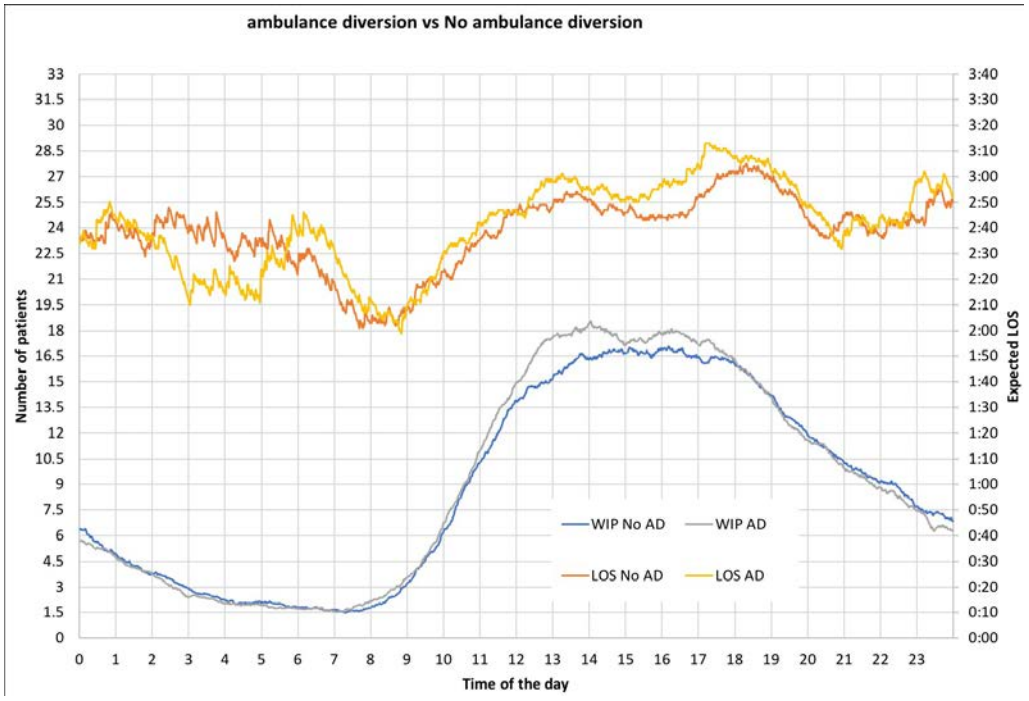

Figure 11: WIP and LOS of ambulance and non-ambulance diversion days

4.3 System state before ambulance diversion

This section presents the results of the analysis of the system state of ambulance and non-ambulance diversion days. This analysis is performed to identify factors that influence the higher WIP of ambulance diversion days and to determine if specific mechanisms can lead to the occurrence of ambulance diversion. The hours just before ambulance diversion will be compared with the same hours during non-ambulance diversion days. To compare the system state of ambulance and non-ambulance diversion days different factors contributing to the arrival, discharge, the WIP and LOS of the patients will be analyzed. Therefore, radiology requests, lab request, nurse availability, type of arrival and discharge way will be examined.

The analysis is based on the sets of comparable days that have also been used in section 4.2. The hours analyzed are from 9:00 until 12:00. This gives better knowledge about what mechanisms could lead to the request of an ambulance diversion. The total number of observed patients in this time frame on the selected ambulance diversion days is 826, while 808 for the non-ambulance diversion days. On average, 13.8 patients arrive each day during the selected 3 hours before ambulance diversion and 13.5 patients arrive during the same hours on non-ambulance diversion days.

Radiology

Radiology requests are subdivided in CT-scans, MRI-scans, X-rays or a combination of these three. The radiology request section in table 5 depicts the number of patients that need or do not need a radiology request, the corresponding percentage and the LOS of these patients. These ’radiology requests’ are analyzed due to the fact that certain radiology requests delay the throughput of the ED. When there are a lot of radiology request during ambulance diversions it is sensible that the WIP increases and this is an indication that it is more difficult to discharge the patients. The results show marginally differences between the ambulance and non-ambulance diversion days.

The ‘type of radiology’ section in table 5, shows the number of patients that need a certain type of radiology, the percentage that needed this and the average waiting time of patients until the scans or x-ray can be executed. This analysis shows that, percentagewise slightly more CT request are made during the hours before an ambulance diversion. Next to having more CT requests, the waiting time for CTs is also higher on ambulance diversion days. The other radiology requests do not differ that much in neither percentage nor time.

Lab requests

The ‘lab request’ section of table 5 shows the number of patients that need a laboratory request for their diagnosis, the percentage of the observed patients that needed a lab request and their average LOS. This comparison was made to determine if the number of lab requests has an influence on the request of ambulance diversion. Patients with a lab request need to wait for the results this could cause a delay and therefore influence the number of patients at the ED. From this table it can be seen that more patients need a lab request before ambulance diversion. Patients that need a lab request have a LOS of almost 80 minutes longer compared to patients not needing a lab request. Therefore, more patients will be longer at the ED during hours before ambulance diversion compared to non-ambulance diversion. It was already expected that on days with ambulance diversion more patients would need a lab request, due to the fact that more patients with a higher complexity arrived on ambulance diversion days (section 4.1.1).

Some patients need a single lab request for the diagnosis while others need multiple lab requests. The analysis of these differences can be found table 11 in appendix A.5. The analysis showed that in terms of time needed to get the results, ambulance and non-ambulance diversion days are almost equal to each other.

Triage code

The 'Triage code' in table 5 shows the number of patients, corresponding percentage and the LOS. The triage code is analyzed as the code indicates a certain care workload for the staff. Therefore, if more complex patients arrive, the staff will have a higher workload. A higher workload can indicate a higher possibility of ambulance diversion requests. Not all patients received a triage code, thus these percentage do not add up to 100 %. As table 5 shows, percentagewise more patient arrive with a U1 and U2 complexity during the hours before ambulance diversion. Patients with a U1 or U2 complexity require on average more nurses to care, compared to other complexities. Therefore, when a U1 or U2 patients arrives, approximately one less nurse is available to care for the other arriving patients. This could influence the need for a request for ambulance diversion.

Next to this, a small difference between the LOS levels can be seen. During ambulance diversion days the U3 patients have a shorter LOS compared to non-ambulance diversion days. However, the U4 and U5 patients have a longer LOS during ambulance diversion days. Nonetheless, these differences between the LOS of the patients are not that large and partly cancel out each other.

Nurse availability

'Nurse availability' in table 5 depicts the average number of nurses present at the ED before ambulance diversion and the registered average number of patients per nurse. The nurse availability system state is checked to determine whether there are less nurses available in the hours before ambulance diversion as opposed to no ambulance diversion. This is done to determine if the number of nurses available has an influence on ambulance diversions. Next to this, it is checked to determine if a higher workload per registered nurse has an influence on ambulance diversions.

The average number of nurses present is calculated by taking the average of the number of nurses present at the ED between 9:00 and 12:00. The registered average number of patients per nurse is calculated by counting the number of patients and dividing them by the number of nurses for each day. An U1 patient needs 2 nurses thus an U1 patient is counted twice and an U2 patient needs 1.5 nurses and is thus counted 1.5 for every patient. 1.5 nurses is chosen due to the fact that, after a while the extra nurse for the U2 patient is available again for other patients according to the ED-personnel. The numbers show that on average the same amount of nurses are available for ambulance and non-ambulance diversion. It was expected that due to the mentioned capacity problems, less nurses would be available on ambulance diversion days.

Table 5 shows that a slightly higher number of patients per nurse is measured on ambulance diversion days, which is mainly due to the higher number of arriving patients with a U1 or U2 complexity as mentioned before.

	Ambulance diversion			No ambulance diversion		
Number of observed patients		826			808	
Radiology request	Number	Percentage	LOS	Number	Percentage	LOS
Radiology requested	433	52.4 %	191	417	51.6 %	191
No Radiology requested	393	47.6 %	138	391	48.4 %	138
Type of radiology	Number	Percentage	Waiting time	Number	Percentage	Waiting time
CT	100	12.1 %	36	66	8.2 %	25
X-ray	274	33.2 %	16	289	35.8 %	17
X-ray + CT	50	6.1 %	87	54	6.7 %	93
Lab request	Number	Percentage	LOS	Number	Percentage	LOS
Lab requested	582	70.4 %	190	532	65.8 %	191
No lab requested	244	29.60 %	109	276	34.2 %	114
Triage code [a]	Number	Percentage	LOS	Number	Percentage	LOS
U0	8	1.0 %	137	0	0.0 %	0
U1	83	10.0 %	167	89	11.0 %	164
U2	299	36.2 %	182	262	32.4 %	184
U3	270	32.7 %	156	280	34.7 %	167
U4	35	4.2 %	176	35	4.3 %	153
U5	91	11.0 %	148	109	13.5 %	135
Nurse availability [b]	Number			Number		
Average number of nurses present	6.4			6.7		
Registered average number of patients per nurse	2.6			2.5		
Arrival type	Number	Percentage	LOS	Number	Percentage	LOS
Ambulance	243	29.4 %	185	239	29.6 %	183
Own transport	375	45.4 %	158	385	47.60 %	163
Specialism	Number	Percentage	LOS	Number	Percentage	LOS
Cardiology	171	20.7 %	154	151	18.7 %	159
Surgery	249	30.1 %	152	286	35.4 %	157
Internal medicine	101	12.2 %	207	98	12.1 %	209
Discharge way	Number	Percentage	LOS	Number	Percentage	LOS
Home	371	44.9 %	150	398	49.3 %	142
Hospitalization	392	47.5 %	191	358	44.3 %	201
Hospitalization steps			Time			Time
Calling until bed available			10			11
Bed available until hospitalization			46			46
Calling until hospitalization			56			57

Note: The waiting time and LOS is depicted in minutes.
Note: Due to incorrect recording of some data the LOS is not always based on the same number of patients.
[a] *As not all patients received a triage level, these percentages do not add up to 100%*
[b] *Measured until 15 October 2017.*

Table 5: Descriptive of the system's state 09:00 - 12:00

Arrival type

Patients can arrive by different means of transport. Table 5 shows the most important types of arrival, which are 'by ambulance' and 'by own transport'. The other arrival types can be found in table 12 in appendix A.5. The number of patients are shown, as well as the corresponding percentage and the LOS. The arrival type is analyzed to determine if the number of patients arriving by a certain type of arrival has an influence on ambulance diversions. Next to this, the LOS is checked to determine the influence of the type of arrival on the LOS of the patients.

The results show that on average more patients arrive by their own transport on ambulance diversion days and that the arrival type influences the LOS. Contrarily, it was expected that more patients would arrive by ambulance, as personnel mentioned that often, before an ambulance diversion request, a long line of ambulances were waiting outside the hospital to deliver patients. Also, due to the higher triage code levels as mentioned before it was expected that more patients would arrive by ambulance.

Specialism

The three specialisms which treat most of the patients are shown in table 5, other specialisms can be found in table 13 in appendix A.5. Table 5 shows the number of patients, the corresponding percentage and LOS. The specialisms are checked to determine if patients with a certain specialism have a longer LOS and if there are more patients arriving with this certain specialism. Then there could be a correlation between these specialisms and ambulance diversion. More cardiology patients and more internal medicine patients arrive during ambulance diversion days. However, differences are small.

Way of discharge

The 'Discharge way' in table 5 shows the most frequently used discharge ways. Other discharge ways can be found in table 14 in appendix A.5. The hospitalization percentage is higher on days with ambulance diversion than without. This means that more patients need to be hospitalized. Next to this, when there are more patients that need to be hospitalized, all beds available at the hospital at that moment could already be occupied by the hospitalized patients. Thus, other patients that arrive at a later moment at the ED and need to be hospitalized cannot be hospitalized due to a lack of beds. However, there was no data available to analyze the number of beds available at the hospital, but it might be interesting for further research to look at the bed availability at the hospital.

Hospitalization takes more time compared to be discharged home. This is due to several steps that needs to be made before a patient can be admitted to the hospital. Admitting a patient to the hospital follows two steps. Step one: The nurse coordinator calls the ward to which the patient must be admitted, to see if there is a bed available. Step two: The nurse coordinator receives a call that a bed is available and personnel will be on their way to the to be admitted patient. The MCL uses a response time of maximum 15 minutes for the wards, from the moment a bed is available until the patient is discharged.

The waiting times of these steps are also shown in table 5. It takes almost the same amount of time for both ambulance diversion and non-ambulance diversion to admit patient to different wards in the hospital. The waiting time to be admitted to the hospital has a strong influence on the LOS of the hospitalized patients.

Conclusion

The system state of the hours before ambulance and non-ambulance diversion shows that there are no large numerical differences, based on the analyzed data. However, the hours before ambulance diversion are characterized by specific patient characteristics. These characteristics consist of more patients needing a lab request and having a longer LOS compared to patients not needing a lab request. These patients occupy the ED for a longer period. Next to this, there are also more patients that need to be admitted to the hospital during ambulance diversion days compared to non-ambulance diversion days. These patients occupy the ED also for a longer period compared to patients that do not need to be hospitalized.

From this it seems that patients needing a lab request and hospitalization have an influence on ambulance diversion. More patients with lab request and patients that need to be hospitalized arrive on ambulance diversion days. These patients have a longer LOS and therefore occupy the ED longer. Next to this, the waiting time to be admitted to the hospital is rather large and could cause congestion in the outflow of patients. These findings can also explain the higher WIP on ambulance diversion days. However, there occurs no specific mechanism in the hours before ambulance diversion days.

4.4 ED rooms occupied by admitted patients

As the observations from 'discharge way' of the system state in section 4.3 show, it takes on average 30 minutes longer to be admitted to the hospital than was agreed. Therefore, a throughput analysis on patients that are admitted to the hospital has been performed. This analysis is done to determine the number of patients that occupy the ED over time as they wait to be admitted to the hospital. This analysis is performed on the data set without distinguishing between ambulance and non-ambulance diversion days, as the longer waiting time to be admitted holds for ambulance and non-ambulance diversion days.

Approximately 45% - 50% of the patients need to be admitted to the hospital. Therefore, the impact of not admitting patients according to the agreed time can be quite large. Figure 12 shows the arrival and departure pattern and figure 13 shows the corresponding WIP and LOS of solely the patients to be admitted.

Figure 12 shows three different departure curves which represent multiple steps it takes to get a patient admitted to the hospital. The hospitalization curve (orange) shows the cumulative number of patients that would leave the ED if they were discharged when the hospitalization order is placed. The bed available curve (grey) shows the cumulative number of patients that would leave the ED if they were discharged when a bed is reported to be available. The departure curve (yellow) shows the actual departure of the patients. The vertical distance between the arrival curve and departure curve consists of multiple "layers". Two of these "layers" are the hospitalization and the bed available layer. As the real departure level is set to zero for midnight, the curves of the hospitalization and bed available start above zero. Thus vertical distance between the arrival curve and the other curves indicate the WIP in a certain stage before departure. From this figure it can be seen that the difference between the hospitalization order and bed available is small. This means that the LOS and WIP for patients measured based on these curves will be relatively similar. It also shows that the difference between the departure curve and the hospitalization and bed available curves is rather large. This indicates a large WIP and LOS difference. This can be explained by the long waiting time to be admitted to the hospital.

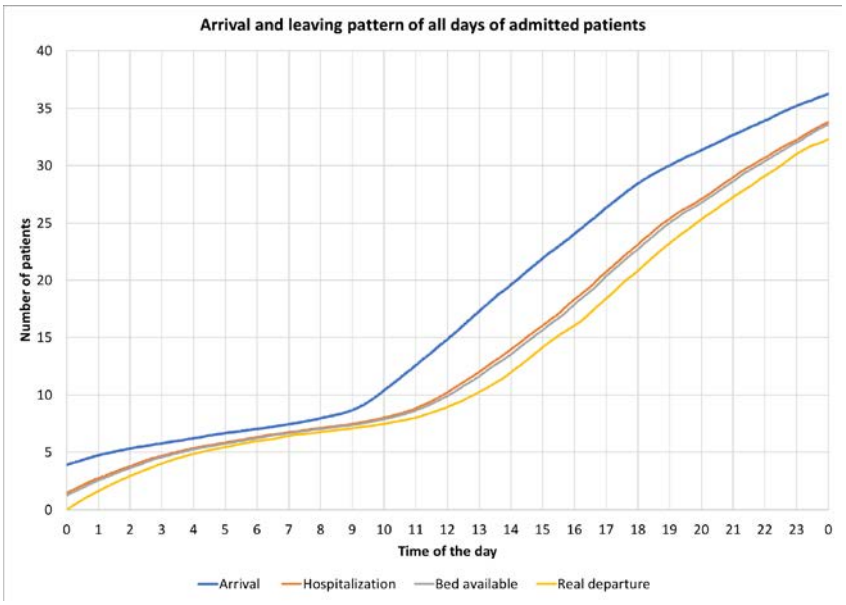

Figure 12: Arrival and departure pattern of admitted patients of all data

Figure 13 shows the WIP based on the hospitalization curve (orange), bed available curve (blue), and real departure curve (green). The figure also shows the LOS of the hospitalization curve (grey), bed available curve (yellow) and the departure curve (blue). The WIP and LOS would decrease if patients could be discharged either at the moment when a hospitalization order is placed or when a bed is available, leading to less patients are occupying the ED. However, it is not possible to discharge the patients at these times, due to the fact that nurses from different wards need to come to the ED to take the patients to the wards. The time that this activity should take is maximum 15 minutes according to standards of the MCL, while currently this time is around 45 minutes throughout the day according to the vertical difference between the blue and yellow curve in figure 13. Thus, if all patients would be admitted according to the agreed time, the WIP and LOS would be significantly lower than currently. The arrows indicate the possible decrease if patient would directly leave at the time a bed has been reported to be available.

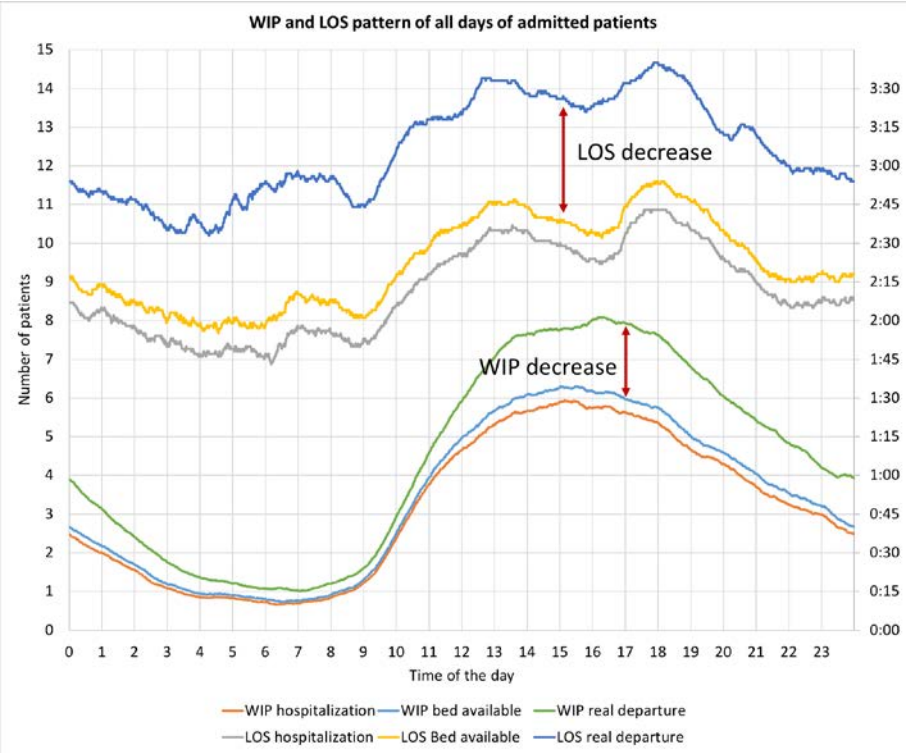

Figure 13: WIP and LOS pattern of admitted patients of all data

4.5 Human factors

From the previous sections it becomes evident that there are no large numerical differences between ambulance and non-ambulance diversion days. However, as the request for ambulance diversion is made by people, the human factor should also be taking into account. Differences between coordinators and possible requests for an ambulance diversion cannot be deducted from the quantitative data. Therefore, the coordinators and the staff at the MCL were observed during different days. The results of these observations can be found in appendix A.6 and the most important findings are discussed in the next paragraph.

While observing the coordinators at the ED of the MCL to determine how different coordinators react on crowding moments, it became evident that coordinators behave differently during crowding moments. For instance, coordinator 1 indicated that an ambulance diversion was perceived as highly needed.[2] This was due to the fact that three hospitalized patients were not picked up yet even though the rooms of these patients would be available within 10 minutes and one high complex care room was still available. At that moment, there were 20 patients at the ED and in the waiting room. Coordinator 2 did not indicate that an ambulance diversion was necessary, even though there were 24 patients at the ED and in the waiting room. Coordinator 2 used one high complex care room as an escape room. These observations illustrate how the perceived pressure and its consequences varies among coordinators. The reasoning to request an ambulance diversion differs, despite having a protocol to use ambulance diversion. The finding of differences in perceived pressure and the difference in requesting ambulance diversion is also confirmed by the report of the MCL (Pietersma, 2018). This is also consistent with the quantitative

[2]the coordinators are anonymized

analysis, which shows there are no clear patterns and mechanisms visible that lead to ambulance diversion. This could indicate that the request for an ambulance diversion is inconclusive and not completely validated.

During the observations it was also visible that some coordinators seem to have a good overview of what needs to be done to discharge or move patients such that ambulance diversion is prevented. Others seem to have less overview to control this flow and prevent ambulance diversion. One way to prevent the request for ambulance diversion used by the coordinators is placing patients back in the waiting room. E.g. patients that need to wait for the lab results or patients with a low urgency are placed in the waiting room, due to the fact that patients with higher urgencies are prioritized. Another observation was that, although some patient were placed back in the waiting room, the available room was not used for the next patient but used as a buffer for when it gets even more crowded. This is mostly done with the high urgency rooms due to the region function of the MCL. However, this is only done by some of the coordinators and there are disputes between staff members whether it is desirable to return patients into the waiting room (Pietersma, 2018). The observations finally show that the nurse coordinators perform a lot of administrative tasks while controlling the flow. The coordinators call the different wards to make sure that the admitted patient will go to the wards. This is done simultaneously with all the other tasks that the nurse coordinators have. The physician coordinators support the nurse coordinator when it gets too crowded to coordinate the patients to the wards.

These observations indicate that there is not a specific standard mechanism that occurs before the request of an ambulance diversion. The decisions that are made before the request of an ambulance diversion are partly subjective due to the human factor involved in this decision and the above mentioned differences between personnel.

5 Discussion & conclusions

This study did not find specific patient flow patterns and mechanisms that typically preceded ambulance diversion. However, the hours before ambulance diversion are characterized by specific patient characteristics. Next to this, the research did identify some other problems in the ED regarding ambulance diversions and the flow of patients. These problems consist of patients occupying the ED as they wait to be admitted to the hospital and the human factor influencing the request for an ambulance diversion.

5.1 Main findings

A preliminary explorative analysis based on the distribution of ambulance diversion showed that most ambulance diversions occurred on Mondays, Wednesdays, Fridays and between 12:00 and 16:00. During these same days on average more patients arrived compared to non-ambulance diversion days. Additionally, the LOS of patients on ambulance diversion days is slightly higher. This could be due to the higher number of arriving patients as it is more crowded at the ED. The characteristics of ambulance and non-ambulance diversion days differ marginally. Numerically there were almost no differences visible, except that there are more patients with a higher complexity.

As a first comparative analysis, the throughput analysis based on comparing days with and without ambulance diversion shows that there is a higher arrival and departure rate on ambulance diversion days. Due to this, more patients arrived on average and the WIP and LOS were higher on ambulance diversion days. It was expected that the WIP during ambulance diversion days would exceed the number of rooms available. Nonetheless, this is not the case as on average the WIP is around the number of rooms. However, the differences between individual days are not taken into account, which could have influenced the findings of this research.

A second analysis has corrected for the overrepresentation of quiet days in the set of non-ambulance diversion days. A ‘control group’ of non-ambulance diversion days was constructed that matched the distributions of weekdays and numbers of arrivals on the days with ambulance diversion. The resulting analysis did not show large differences. It was expected that during the morning the WIP of ambulance diversion would be larger compared to a non-ambulance diversion day. A small difference has been observed as the arrival rate was slightly higher in the morning on ambulance diversion days.

Thirdly a system state analysis has been performed to determine more detailed system state characteristics before the ambulance diversion and its differences with the "control group". The analysis shows that there are hardly any numerical differences between ambulance and non-ambulance diversion days. However, there are patient characteristics that characterize these hours before ambulance diversion. These patient characters tics consist of a higher number of patients needing lab requests and needing to be hospitalized. These patients, have a longer length of stay compared to patients not needing lab requests or hospitalization. This means that they occupy the ED for a longer period of time and therefore occupy the ED and the workload of the personnel for a longer time. Additionally, the outflow of patients to the hospital has some delay. On average patients waited for more than 30 minutes to be discharged to the wards in the hospital.

Lastly, during the observations at the ED it was visible that coordinators behave differently

during crowding. Some coordinators kept a good overview of the crowding state of the ED and gave guidance to what needs to be done to prevent an ambulance diversion. As others seem to have less overview during these busy moments. Also the nurse coordinator seems to be very busy with all sorts of different administrative tasks, while trying to keep the flow at the ED optimal. Especially, keeping the outflow of patients to different wards going can be a busy task for the coordination nurse and therefore there is less time available to do other tasks. The pressure on room availability can largely be reduced by earlier transport of patients that have already been assigned a bed in a ward.

5.2 Limitations

This study has some limitations. Due to being a single case study there can be a selection bias as the MCL has a lot of ambulance diversion episodes. However, it is an appropriate case to execute this study due to the high amount of quantitative data available concerning ambulance diversions. The ED of the MCL is one of the largest EDs of Northern-Netherlands. Therefore, performing this research at hospitals with a different size does not necessarily lead to the same results. Research at hospitals with a different size and less ambulance diversions should be performed to increase the generalizability of this study.

The methods and sources in this cases consisted of: quantitative analyses based on retrospective data, qualitative data and observations. Due to the fact that the study is a casestudy the completeness and accurateness of registration of the data relies on the hospital. As found during the analysis, this data set is not always complete and sometimes data could not be used due to incorrect recording. Another data limitation is that only analyses from the perspective of patient data is performed. Initially, the plan was also to have data available of the bed utilization at the hospital. However, this data was not available which limits the research.

Another limitation in this research is the fact that the data is based on different layouts of the ED as a new ED building has been taken into use during the measurement period.

The focus on the analysis correcting for quiet days can create a selection bias, as ambulance diversion does not solely happen between 12:00-14:00. Still, this interval is rather large, to qualify the time-frame from 9:00 and 12:00 as the preceding hours to analyze preceding patterns. However, this could be a reason that there were no large differences visible. Additionally, in this analysis the individual days are also not taken into account.

By using a report of the MCL itself for the qualitative analysis, the completeness and accurateness relies on the questions asked by the internal consultant. Next to this, this report was based on interpretations of the personnel and did not use questions based on quantitative data.

The observations at the ED are limited due to personal interpretations and the fact that personnel can behave differently, knowing that they are observed during the day. Nonetheless, because of the observations it was possible to have a better understanding about how the ED behaves. However, no ambulance diversion occurred during the observations. Yet due to the fact that during the observation it was busy on some days, it was still possible to have a good understanding on what happens when the ED is on the edge of requesting an ambulance diversion.

5.3 Future research

It is recommended to improve the generalizability of the findings of this study. Next to this, it is recommended to look more at the human factor influencing the ambulance diversion and then specific looking at the role of the coordinators. As this research found that the human factor can play a role in the request of an ambulance diversion. Another recommendation is to look more into the influence of the bed availability at the hospital, as this has not been researched in this study due to lack of data. It is also recommended to have a look at the spread of the system state and the influences the different factors have on each other.

5.4 Managerial implications

Due to the fact that no large differences were found between ambulance and non-ambulance diversion days, a managerial opportunity rises to develop a more general control approach of the patient flows in the ED. This is because it makes little sense to focus solely on the ambulance diversion moments. Additionally, a managerial recommendation is to create an overview of the decisions staff makes on ambulance and non-ambulance diversion days, such that the differences between those days can be documented and researched. Another opportunity rises in redesigning the outflow of patients to the hospital, such that a comprehensive solution will be found to decrease the time between being admitted to hospital and the real discharge to the hospital. Finally, a managerial opportunity lies in designing an ambulance diversion protocol in such a way that no disputes will rise between staff at the ED and ambulance diversion will only be requested if it meets the requirements of the protocol. The human factor should be taken into account when redesigning this protocol.

5.5 Conclusions

In general, no specific patient flow patterns have been found to precede ambulance diversions. The findings of this study confirm the findings of the ambulance diversion literature that used regression analysis. However, the results of this study do not provide specific patient flow patterns and clear mechanisms as an indication for ambulance diversion. The study did provide some indications of differences in the ED status preceding ambulance diversion. In general it was preceded by more patients needing lab requests and hospitalization. Additionally, these patients have a longer LOS as opposed to patients not needing lab requests or hospitalization during the hours before ambulance diversion. The observational part of the study indicated that a high workload due to the variety of tasks of the coordinator might restrict the opportunities to be responsive in speeding up the outflow of admitted patients. Finally, an integrated look at the flow of the ED, which includes looking more at the role of the coordinator during ambulance diversion, could improve the prevention of ambulance diversion.

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Appendix

A.1 Ambulance diversion characteristics

	No ambulance diversion		Ambulance diversion		3 hours before ambulance diversion	
	Percentage	LOS	Percentage	LOS	Percentage	LOS
Ambulance	32.48 %	181	32.75 %	184	31.26 %	199
Eigen vervoer	42.60 %	148	43.04 %	155	45.33 %	164
Helikopter	1.25 %	177	1.14 %	181	0.96 %	186
NULL	11.64 %	164	12.66 %	170	12.04 %	182
Openbaar vervoer	0.09 %	132	0.06 %	149	0.03 %	192
Overig	9.60 %	137	7.99 %	144	8.21 %	149
Politie	0.14 %	133	0.14 %	151	0.07 %	292
Rolstoel	1.25 %	163	1.42 %	161	1.36 %	178
Taxi	0.77 %	159	0.60 %	173	0.57 %	178
Uit voertuig helpen	0.01 %	149	0.01 %	157	0.03 %	157
Ziekenhuistransport	0.17 %	179	0.20 %	158	0.13 %	151

Table 6: Distribution of the arrival types on ambulance and non-ambulance diversion days

	No ambulance diversion		Ambulance diversion		3 hours before ambulance diversion	
	Percentage	LOS	Percentage	LOS	Percentage	LOS
Anaesthesiologie	0.00 %	88	x	x	x	x
Bijzondere tandheelkunde	0.01 %	43	x	x	x	x
Cardio-pulmonale chirurgie	0.52 %	146	0.73 %	136	0.63 %	146
Cardiologie	16.65 %	159	17.53 %	162	17.29 %	165
Chirurgie	31.43 %	145	30.13 %	151	30.26 %	160
Dermatologie	0.03 %	121	0.02 %	100	x	x
Gastro-enterologie (Maag-darm-lever)	2.87 %	191	3.09 %	196	3.59 %	204
Geriatrie	1.38 %	238	1.52 %	230	1.96 %	240
Hematologische Intensive Care	0.00 %	252	x	x	x	x
Intensive Care	0.47 %	156	0.54 %	155	0.40 %	135
Inwendige geneeskunde	14.19 %	199	14.86 %	204	14.43 %	216
Keel-, neus- en oorheelkunde	0.53 %	89	0.47 %	89	0.30 %	122
Kindergeneeskunde	0.52 %	129	0.47 %	138	0.30 %	193
Longziekten	7.86 %	187	8.71 %	191	9.28 %	204
MKA Chirurgie	0.18 %	115	0.14 %	112	0.10 %	145
Neurochirurgie	0.01 %	308	0.01 %	209	x	x
Neurologie	9.42 %	183	9.68 %	187	9.98 %	201
NULL	0.01 %	4	0.01 %	1	x	x
Oncologie	0.24 %	211	0.19 %	189	0.17 %	254
Oogheelkunde	0.14 %	59	0.07 %	63	0.20 %	65
Orthopedie	5.73 %	132	4.34 %	143	4.09 %	156
Plastische chirurgie	2.27 %	116	2.11 %	126	1.70 %	147
Psychiatrie	0.00 %	91	0.01 %	197	0.03 %	197
Reumatologie	0.20 %	197	0.14 %	204	0.17 %	279
Spoed Eisende Hulp	2.98 %	38	2.87 %	43	2.99 %	47
Urologie	2.07 %	150	2.08 %	150	1.96 %	152
Verloskunde en gynaecologie	0.29 %	173	0.27 %	172	0.17 %	193

Table 7: Distribution of the specialisms on ambulance and non-ambulance diversion days

A.2 Throughput diagrams single days

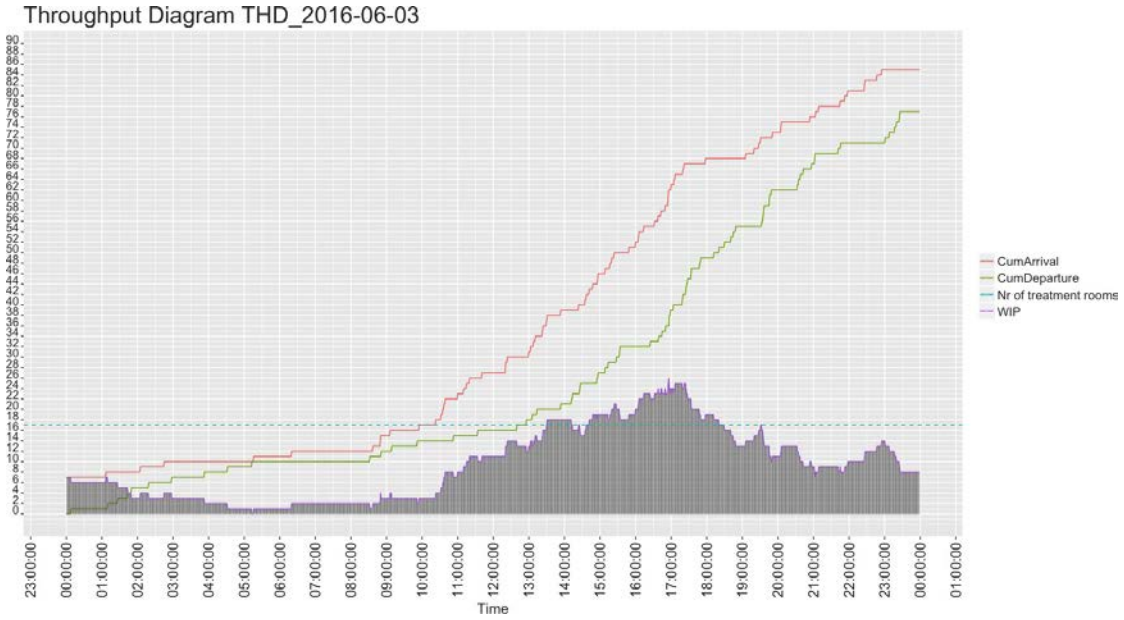

Figure 14: Throughput diagram ambulance diversion day 3 July 2016

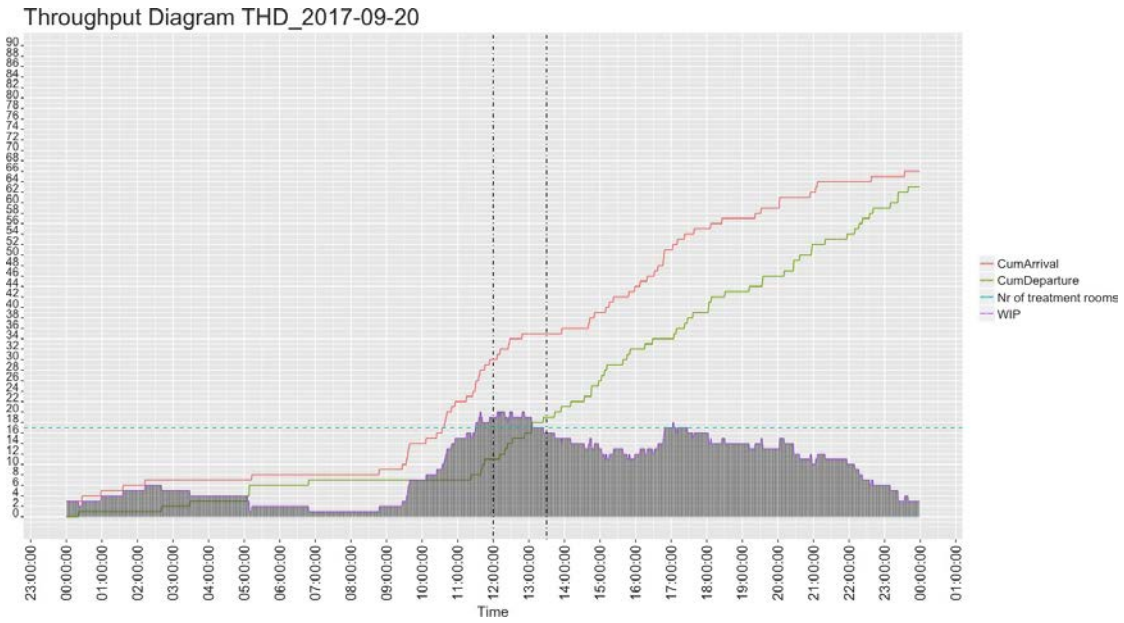

Figure 15: Throughput diagram ambulance diversion day 20 September 2017

A.3 Set of days for throughput analysis

Weekday	Date non-ambulance diversion	Amount of arrivals	Date ambulance diversion	Amount of arrivals
Friday	2016-06-10	98	2017-05-26	100
Friday	2016-05-13	88	2016-11-04	88
Friday	2016-09-16	87	2017-04-14	87
Friday	2016-06-17	85	2016-10-28	85
Friday	2017-03-17	85	2017-01-06	85
Friday	2016-12-23	83	2018-01-19	84
Friday	2016-04-22	81	2016-04-15	81
Friday	2016-06-24	81	2017-12-29	81
Friday	2017-08-11	80	2017-07-07	80
Friday	2018-01-12	78	2018-01-05	78
Friday	2017-06-23	73	2017-04-28	73
Monday	2016-09-12	102	2016-10-24	96
Monday	2017-05-22	99	2016-11-07	95
Monday	2017-04-10	90	2018-03-12	95
Monday	2018-02-05	89	2017-10-09	91
Monday	2017-01-16	88	2016-09-19	89
Monday	2017-01-30	88	2017-05-15	86
Monday	2018-02-19	87	2017-07-03	85
Monday	2017-07-10	84	2017-02-20	84
Monday	2016-10-10	84	2017-08-14	84
Monday	2017-06-19	83	2017-03-20	83
Monday	2017-02-13	82	2017-01-02	82
Monday	2017-04-03	81	2018-01-08	82
Monday	2016-05-16	73	2018-01-01	73
Monday	2017-05-01	72	2017-12-04	72
Monday	2016-10-31	70	2017-02-27	70
Monday	2017-04-17	64	2016-11-28	65
Monday	2016-06-13	62	2017-08-28	62
Saturday	2016-05-28	83	2017-09-23	83
Saturday	2016-07-09	73	2016-11-12	73
Saturday	2018-01-20	70	2018-01-27	70
Saturday	2017-01-21	60	2016-12-31	61
Sunday	2017-04-16	76	2017-04-30	76
Sunday	2017-07-09	74	2017-01-22	74
Sunday	2016-07-10	62	2017-09-17	62
Sunday	2018-01-14	55	2016-12-11	55
Thursday	2016-05-26	93	2017-06-22	94
Thursday	2017-06-15	91	2018-01-11	92
Thursday	2018-02-01	82	2017-03-23	82
Thursday	2017-07-06	79	2018-03-08	80
Thursday	2017-08-31	77	2017-04-06	77
Thursday	2016-10-27	75	2017-01-05	75
Thursday	2017-05-18	73	2016-04-07	73
Thursday	2017-10-26	64	2017-07-20	64
Tuesday	2016-04-26	91	2017-06-27	90
Tuesday	2016-08-23	86	2018-01-09	86
Tuesday	2016-09-20	85	2017-10-17	85
Tuesday	2018-02-13	71	2018-03-13	71
Tuesday	2018-01-16	61	2017-08-08	62

Weekday	Date non-ambulance diversion	Amount of arrivals	Date ambulance diversion	Amount of arrivals
Wednesday	2017-06-14	91	2017-03-01	91
Wednesday	2017-02-15	87	2017-04-26	87
Wednesday	2016-06-22	86	2017-10-11	86
Wednesday	2016-11-16	80	2017-02-08	80
Wednesday	2017-05-10	78	2017-01-11	78
Wednesday	2016-06-08	75	2017-01-25	75
Wednesday	2018-02-14	70	2016-10-26	70
Wednesday	2016-09-21	67	2016-11-23	67
Wednesday	2017-08-23	67	2017-08-09	67
Wednesday	2018-03-28	65	2017-09-20	65
Wednesday	2017-05-31	62	2017-12-06	63
Average		78.8		78.8

Table 8: Number of patients and day for same day same number of arrivals

A.4 Analysis same day, arrival and WIP

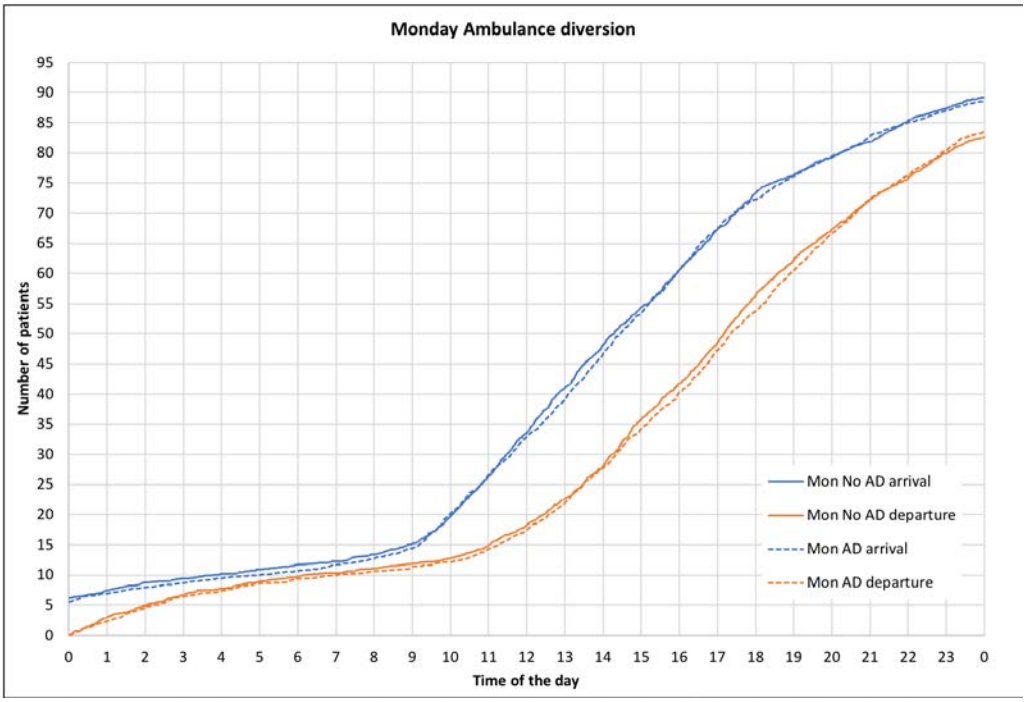

Figure 16: Arrival pattern Monday

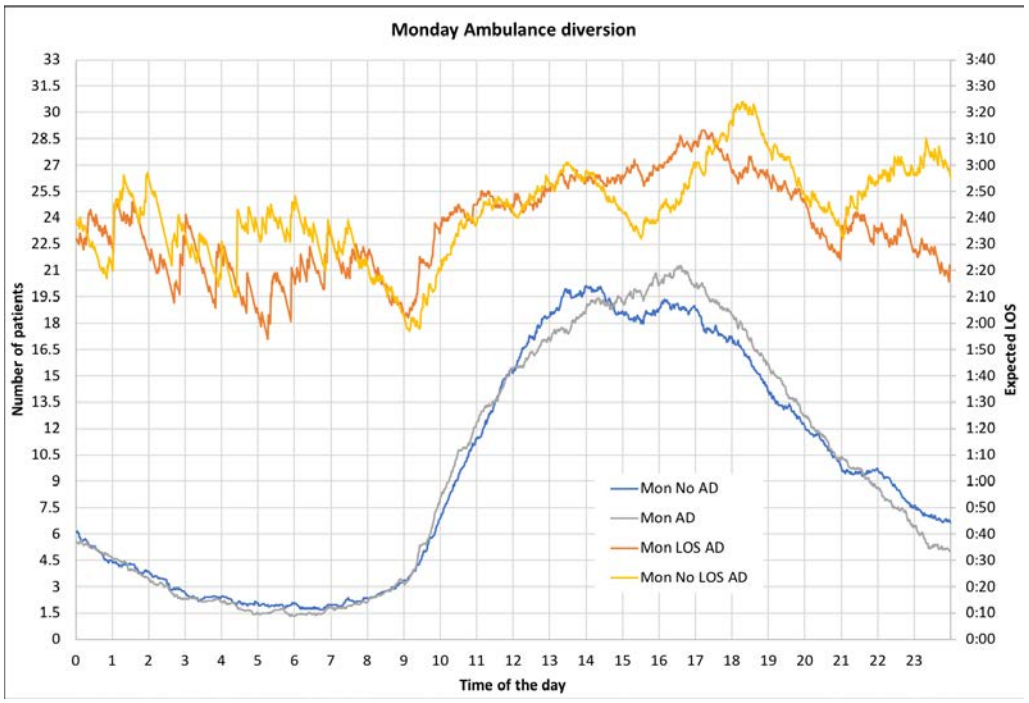

Figure 17: Work in progress and length of stay Monday

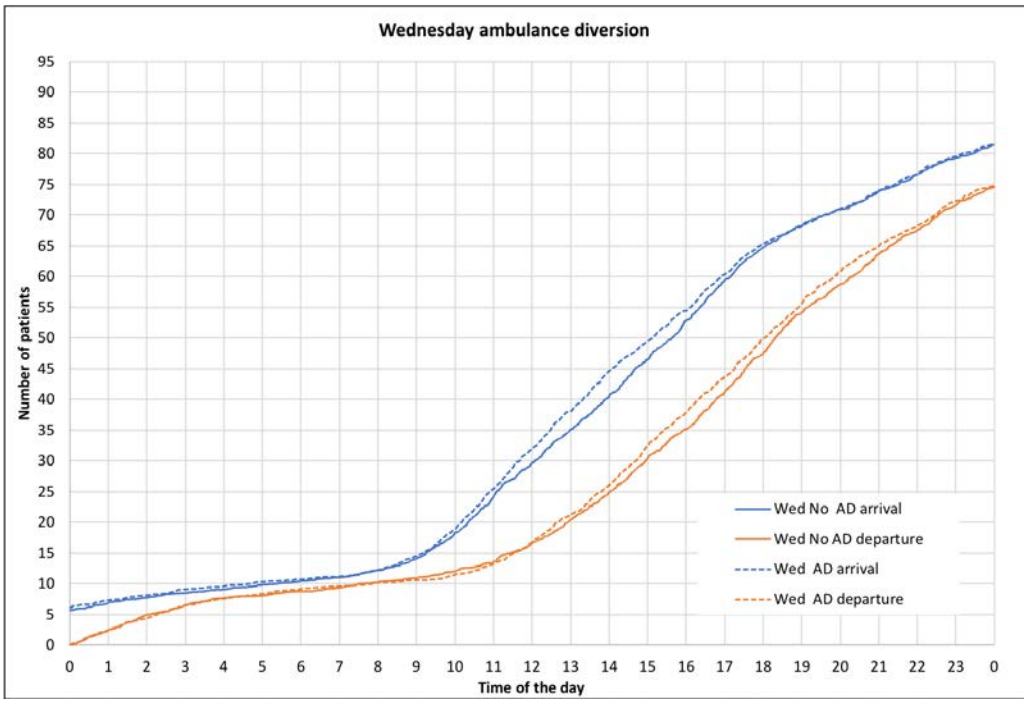

Figure 18: Arrival pattern Wednesday

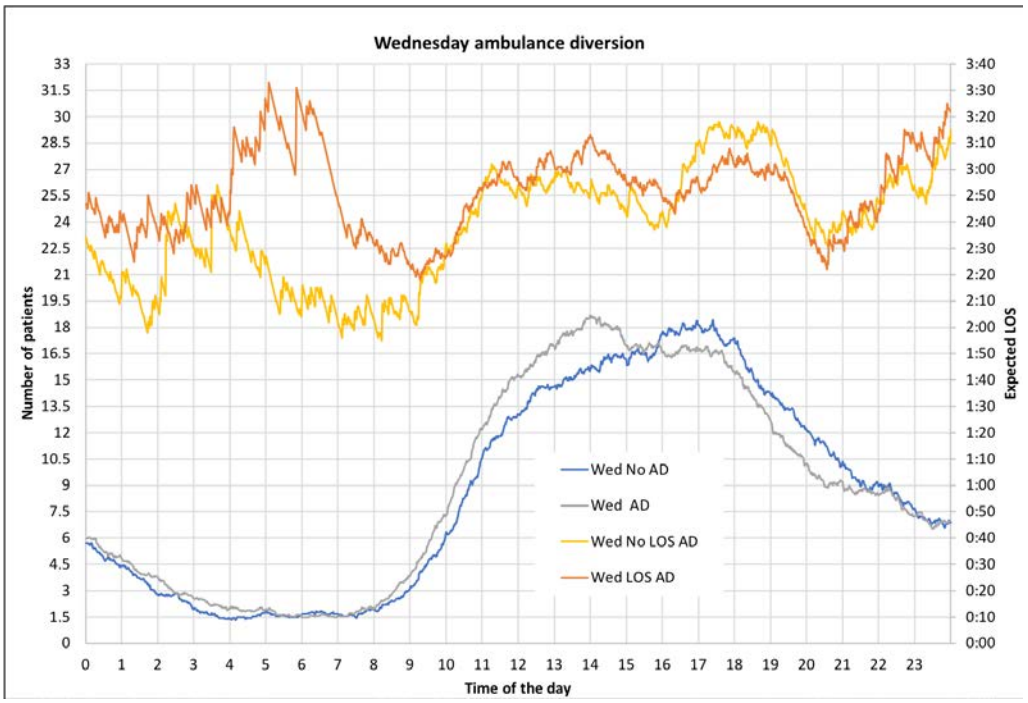

Figure 19: Work in progress and length of stay Wednesday

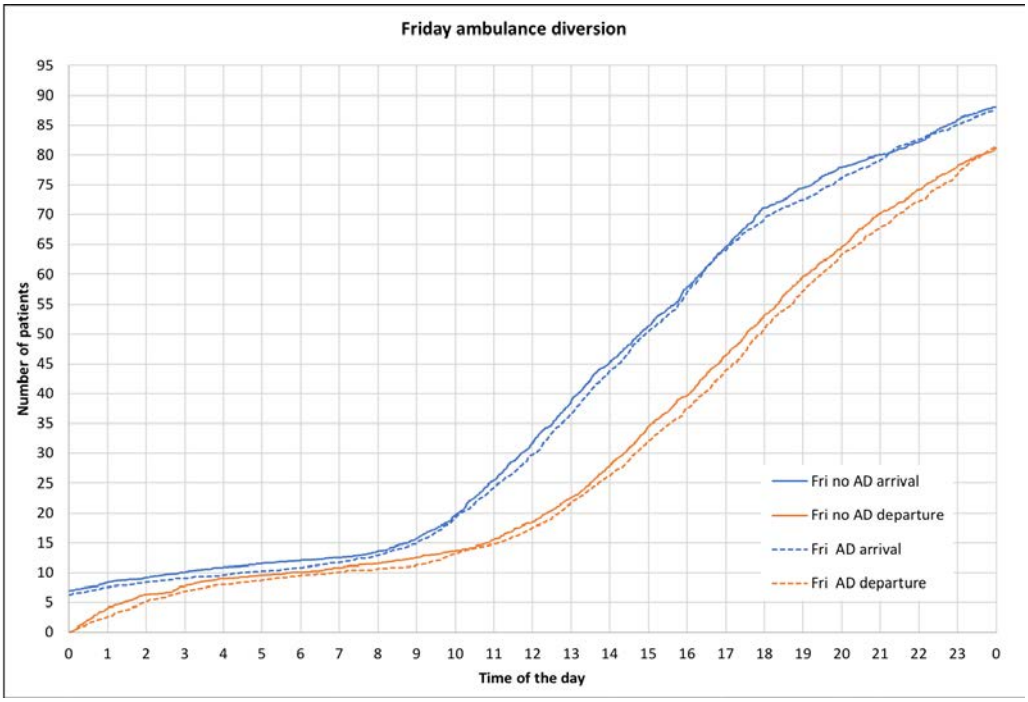

Figure 20: Arrival pattern Friday

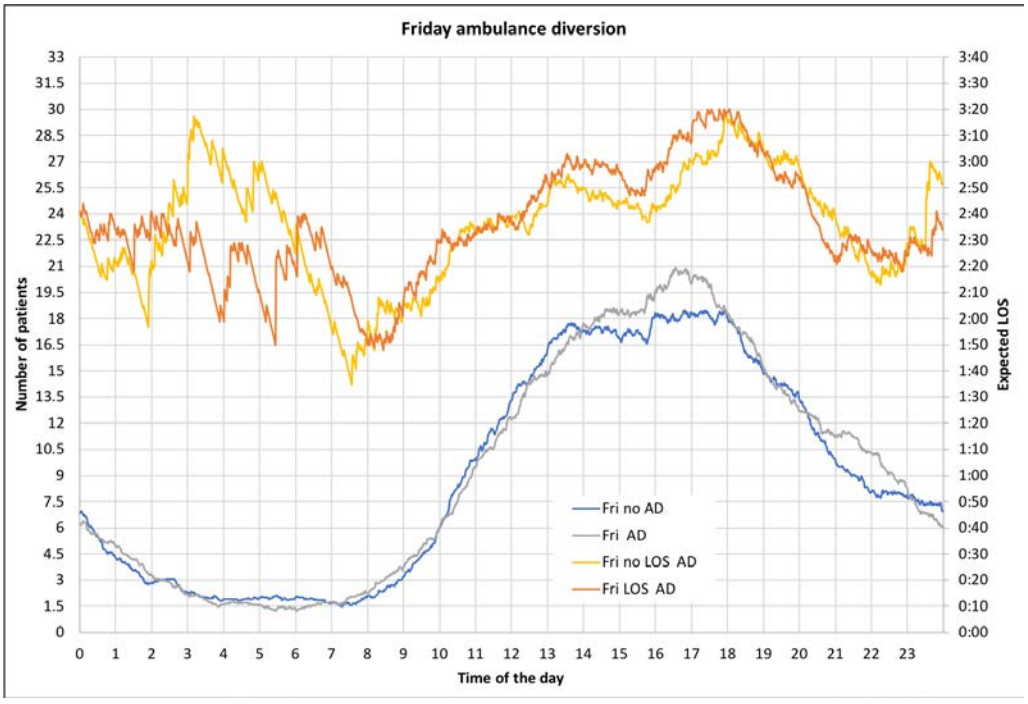

Figure 21: Work in progress and length of stay Friday

A.5 System state

	Ambulance diversion			No ambulance diversion		
Number of observed patients		4730			4726	
Number of patients overall[a]	Number	Percentage	Waiting time	Number	Percentage	time
MRI overall	39	0.8 %	47.1	39	0.8 %	29
CT overall	797	16.8 %	23.1	795	16.8 %	21.3
X-ray overall	2012	42.5 %	14.4	2096	44.4 %	15.8
X-Ray + CT overall	289	6.1 %	80.5	314	6.6 %	83.6
Number of patients 09:00-12:00	826			808		
MRI	5	1.1 %	73	3	1.0 %	unknown[b]
CT	100	12.1 %	36	66	8.2 %	25
X-ray	274	33.2 %	16	289	35.8 %	17
X-ray + CT	50	6.1 %	87	54	6.7 %	93
X-ray + MRI	1	0.1 %	unknown[b]	2	0.2 %	unknown[b]
MRI + CT	3	0.4 %	unknown[b]	3	0.4 %	unknown[b]

[a] *The number of patients overall is the cumulative number of patients that arrived on the ambulance and non-ambulance diversion days correcting for quiet days.*
[b] *Due to the fact that not all times regarding request are recorded there is no record available for the waiting time of an MRI request during non-ambulance diversion days in the 9:00-12:00 time frame.*
Note: The percentages next to the amount of patients are the amount of patients requesting a certain radiology request compared to the total amount of that classification. Thus they do not add up to a hundred percent.

Table 9: Radiology request on the same day and same arrival distinguished in the overall days and the hours before ambulance diversion.

	ambulance diversion			No ambulance diversion		
	Number	Percentage	LOS	Number	Percentage	LOS
Amount of patients overall	4730			4726		
Labrequest Yes	3289	69.5%	190	3022	63.9%	190
Labrequest No	1441	30.5%	111	1704	36.1%	111
Amount of patients 09:00-12:00	826			808		
Labrequest Yes	582	70,4%	190	532	65.8%	191
Labrequest No	244	29.6%	109	276	34.2%	114

Table 10: Descriptive statistics lab requests

Lab request 9:00 -12:00	Ambulance diversion	No Ambulance diversion
One labrequest		
Time it takes to get first results	25	24
Time it takes to get total results	83	78
Multiple labrequests		
Time it takes from first request to first results	29	24
Time it takes from last request to last results	62	70
Time it takes from first request to last results	123	131

Table 11: Results of the lab requests 09:00-12:00

09:00-12:00	ambulance diversion		No ambulance diversion	
arrival type	Amount	percentage	amount	Percentage
Ambulance	488	31.2%	391	26.7%
Eigen vervoer	687	44.0%	727	49.6%
Helikopter	19	1.2%	18	1.2%
NULL	193	12.3%	152	10.4%
Openbaar vervoer	1	0.1%	0	0.0%
Overig	135	8.6%	131	8.9%
Politie	1	0.1%	1	0.1%
Rolstoel	26	1.7%	24	1.6%
Taxi	10	0.6%	16	1.1%
Uit voertuig helpen	1	0.1%	0	0.0%
Ziekenhuistransport	2	0.1%	6	0.4%

[a] *The percentage is based on the cumulative arrivals as mention section 4.3*

Table 12: arrival type distribution during the hours 09:00-12:00

	Ambulance diversion		No ambulance diversion	
Specialism	Number	Percentage	Number	Percentage
Cardio-pulmonale chirurgie	9	0.58 %	7	0.48 %
Cardiologie	304	19.45 %	243	16.58 %
Chirurgie	453	28.98 %	510	34.79 %
Gastro-enterologie (Maag-darm-lever)	54	3.45 %	48	3.27 %
Geriatrie	34	2.18 %	25	1.71 %
Intensive Care	5	0.32 %	4	0.27 %
Inwendige geneeskunde	224	14.33 %	181	12.35 %
Keel-, neus- en oorheelkunde	5	0.32 %	5	0.34 %
Kindergeneeskunde	2	0.13 %	3	0.20 %
Longziekten	148	9.47 %	137	9.35 %
MKA Chirurgie	2	0.13 %	1	0.07 %
Neurologie	161	10.30 %	145	9.89 %
Oncologie	2	0.13 %	2	0.14 %
Oogheelkunde	2	0.13 %	2	0.14 %
Orthopedie	45	2.88 %	37	2.52 %
Plastische chirurgie	32	2.05 %	31	2.11 %
Reumatologie	3	0.19 %	1	0.07 %
Spoed Eisende Hulp	48	3.07 %	62	4.23 %
Urologie	28	1.79 %	20	1.36 %
Verloskunde en gynaecologie	2	0.13 %	2	0.14 %

Table 13: Specialism and percentage during the hours 09:00-12:00

09:00-12:00	**Ambulance diversion**		**No ambulance diversion**	
Discharge-way	Amount	percentage	Amount	Percentage
Externe Instelling	10	0.6%	14	1.0%
Mortuarium	3	0.2%	4	0.3%
NULL	84	5.4%	71	4.8%
Ontslag/Huis	675	43.2%	706	48.2%
Opname	774	49.5%	658	44.9%
Overig	2	0.1%	1	0.1%
Polikliniek	13	0.8%	9	0.6%
Tegen medisch advies	2	0.1%	3	0.2%

[a] *The percentage is based on the cumulative arrivals during the hours 09:00-12:00. The cumulative arrivals are for ambulance diversion 826 and for no ambulance diversion 808*

Table 14: Discharge way and percentage during the hours 09:00-12:00

A.6 observations

Observations

To have a more clear understanding on how the ED of the MCL behaves during the day, field notes were made during observations at the ED. These field notes consists of some observations and questions asked to the ED-personnel. The most important notes are depicted here.

- During quiet mornings everyone is calmly treating the patients and there is no pressure to work faster. However, when it gets busier the personnel must suddenly work harder to keep up with the arriving patients, and patients that are already long at the ED must be discharged immediately. This results in a little bit stressed personnel.
- When it is busy and patients need to be admitted to the hospital it is possible that the personnel (coordination nurse) does not have a good overview that some patient are waiting for almost an hour to be admitted. To call the wards that patients are still waiting to be admitted is a time-consuming task during busy hours.
- Some coordinators try to have an "escape room", such that trauma patients can still arrive at the ED although it is busy at that moment. The "escape room" is a high complex room that the coordinators tries to keep free to create a buffer, in case the room is suddenly necessary.
- The triage system is not always used, personnel tends to look more at the description of the patients than to look at the triage of the patient. As explained by a physician: "If a patient arrives with a broken bone sometimes he receives triage code 2, at the same time another patient arrives at the ED and gets triage code 4 because he has acute pain in the abdomen. Then the second patient with triage code 4 is prioritized due to the fact that is perceived more acute.
- Sometime ambulances arrive at the ED within 5 minutes after the ED received a call for a new patient. This means that the ED cannot anticipate well on these ambulance delivered patients.
- Some coordinators request an ambulance diversion if they think the ED is full, although there are patients that will be leaving the ED in 30 minutes. As others only request ambulance diversion if the ED is full and it is certain that no patient will leave the ED within 30 minutes.
- During the observations it appears that the current lay-out of the ED at the hospital does not give a complete overview on what is happening. The coordinators are at the high complex rooms of the ED and therefore have less overview on what is happening at the medium and low complex care rooms. Also, when it is busy at the ED it does not appear to be busy. For the patients' sense this could be good as they can lay quietly in their rooms. However, due to the fact that it is not perceived as busy, although it is busy at that moment, patients can be dissatisfied as they think that they are not treated quickly enough. Next to this, the perceived pressure differs for the personnel. E.g. at the low complex rooms it could be quiet and thus it is perceived as not busy, although all high complex rooms are occupied meaning that it is busy at the high complex part of the ED, but this is not visible for the personnel at the low complex part.