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Performance analysis and improvement at the Acute Admissions Unit of Maxima Medical Centre

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Performance analysis and improvement at the Acute Admissions Unit of Máxima Medical Centre

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Management summary

This report describes the final project I performed to end my study Operation Management and Logistics at Eindhoven University of Technology. The study was performed at the Acute Admissions Unit (AAU) of Máxima Medical Centre (MMC), location Veldhoven.

MMC is a hospital which consists of two sites, one in Veldhoven and one in Eindhoven. On September 1, 2008, MMC changed greatly; the location profiles were changed, the Emergency Department (ED) in Eindhoven was closed and all acute care was concentrated in Veldhoven. As from this date, also a new ward was introduced in MMC Veldhoven the AAU. This unit is an intermediate ward between the ED and the regular wards. The AAU makes sure that patients at the ED can always be admitted, and that the outflow to regular wards is predictable. Patients can stay for a maximum of 48 hours at the AAU before the patient is either discharged or transferred to a regular ward.

The concept AAU has only been applied to two other hospitals in the Netherlands, so little is known about AAUs. Also in literature only few articles have been written about AAUs. Although the design of the AAU was made consciously, problems were expected. It is therefore essential that from the moment the AAU is opened all relevant performance measures are used to assess the performance of the AAU. This performance analysis could help in determining where improvements are needed. When improvements are needed, these need to be found to ensure the benefits of having the AAU at MMC.
The project's objective was formulated as follows:

Develop a model that gives insight in the performance and possible improvements of the processes executed at the acute assessment unit.

The objective could not be attained immediately; first several steps were needed to reach the objective. All these different steps have been formalized in seven research questions. The first research question is: What are the processes at the AAU. In this report the processes at the AAU have been captured and classified in an inflow, stay and an outflow phase. This research question has also led to the insight that not only the processes at the AAU itself should be assessed, but also diagnostic tests and treatment that is done elsewhere in the hospital has an influence on the AAUs performance. Therefore also the processes at the Lab, Radiology, Surgery and function department have been described in relation to the AAU.

After that, performance measures were looked for to assess the performance of the AAU, which is the second research question. With the use of the literature study (Diepeveen, 2008) which was performed prior to this project, a selection was made for relevant performance measures. These performance measures were subdivided into four performance dimensions: time, costs, flexibility and quality. Besides the use of the literature study, also other more AAU specific literature was inspected for additional performance measures. Lastly, MMC sources were also used to determine relevant performance measures. The reader is referred to chapter 3 for a full list of all performance measures, but to give an idea the following type of performance measures are used: access time, length of stay, throughput time, queue time, tardiness and bed utilization.
For several of these performance measures also targets were set, which answers the next research question: *What is the desired/intended performance of the AAU on the selected performance measures?*

The analysis of the performance measures can only be performed, when the right data is available, the fourth research question considers the data: *What data is needed to assess the performance measures and how can this data be gathered?* Most of the needed data was gathered by information systems and could be retrieved for analysis. For these performance measures data is used from September to November to assess the performance. For the performance measures related to the detailed

performance analysis of the transfer of patients and the visiting rounds, nurses were asked to gather the needed data. For these performance measures data is only available for November. Then there is also some data which is needed to assess performance measures, but that could not be gathered. So the analysis made is not the ideal analysis, because not all performance measures could be assessed, but the most relevant performance measures could still be assessed. So the analysis made is still very broad and for some parts also very detailed.

The next research question, *What is the current performance of the AAU on the chosen performance measures?*, contained more than only answers to the performance on the performance measures. In the performance analysis also much insight was gained in the properties of the processes at the AAU. The analyses showed that the AAU is in general performing well; most expected improvements were gained with the introduction of the AAU. A summary of the performance on several important measures is given in the table below It has been shown that the Hospital Length of stay for acute patients has reduced after September in comparison to the situation before September. Furthermore the expected fraction of patients discharged within 4 hours at the AAU, which was set at 80%, was achieved with an average of slightly below 90%. Thirdly, the fraction of patients discharged at the AAU is with 46%, 6% higher than projected. These three performance measures have shown the AAU performs well. However, there are also several performance measures which show that improvement is possible and needed.

Month	Number of admissions	Average AAU LoS (in days)	Sum of nursing days	Average number of beds utilized	Bed utilization
September	516	1.08	541.22	18.04	64%
October	532	1.14	606.59	19.57	70%
November	525	1.28	665.74	22.96	72%

First, It was found that the ED-AAU access time, the time it takes from the start time at the ED till the patient is at the AAU, is often longer than the norm. The throughput time at the ED should be smaller than 3 hours, but since the ED-AAU access time is on average 2.72 hours, a large proportion of patients coming from the ED, more than 30%, is not admitted to the AAU within 3 hours.
Then with regard to the visiting rounds that are done at the AAU, also show some worrying behaviour was identified. The afternoon visiting round, often starts later than 16:00. This is the case for practically all specialties. When visiting rounds are done too late, it is difficult to timely transfer patients to other wards. The transfer of AAU patients to regular wards should in principle take place before 18:00, but is often violated. Furthermore at the evening visiting rounds relatively few outflow decisions are taken.
A second problem of the visiting rounds is the accompanying of consultants. The visiting rounds are poorly accompanied by consultants from the specialties ACH and ORT. The poor performance of the ACH specialty is due to the absence of consultants at the afternoon visiting rounds, whereas ORT consultants are absent at both visiting rounds about 40% of the time during November. The limited presence of consultants can result in a less effective visiting round, which can lead to longer AAU lengths of stay.
In the performance analysis also the connection of the visiting rounds with other departments has been assessed. It was found that the connection of the 8:00 lab round is poorly with the morning visiting round. For example at 8:30, 40% of the visiting rounds have started while less then 10% of lab results are known, and at 9:00 when 80% of the visiting rounds have started only 40% of lab results are known. The absence of the latest lab results at the time the visiting round is done, limits the effectiveness of that visiting rounds. Doctors have to decide on the treatment plan based on incomplete data, or have to come back later to reflect on the lab results, causing extra work. This is all undesirable, and improvements are badly needed.
The performance analysis also reflected on the performance of the radiology department, also in relation to the different visiting rounds. The strict norm of the radiology department is that from the moment a radiology test is requested for patients staying at the AAU, the test should be finished and reported within 24 hours. This is only achieved in 84% of the cases. It is however more desirable

when the requested radiology tests are finished and reported before the next visiting round, then doctors can immediately take the performed test into account. When this more difficult to attain norm is used even less radiology tests are performed in time. One of the problems for the long throughput time is the long wait time, the time it takes from the moment the test has been performed, before the results are released. The wait time for radiology tests is on average 6.44 hours. So the performance at the radiology department needs improvement.
The last finding of bad performance concerns the transfer of patients at the AAU to the regular wards. It was found that, although in principal no transfers are allowed to take place after 18:00, these did occur. There are several reasons for these 'night' transfers. First of all, sometimes patients cannot be transferred sooner, because no bed is available at the receiving ward. Second, when more patients than anticipated flow in at the AAU, the AAU has to transfer some patients to assure its receiving function. This has also caused for transfers after 18:00. The 'night' transfers have caused workload problems at the regular wards, so these transfers should be avoided as much as possible.

The performance analysis has showed some problem areas which need to be improved, the sixth research question has dealt with this issue. Of these performance problems only three were further dealt with, because of the scale of a master thesis project, the impact of the possible improvement, and the attractiveness of solving the problem. The following three problems were chosen:

- The late evening visiting round at the AAU
- The bad connection of the 8 o'clock lab round with the morning visiting round.
- The lack of insight at the AAU in the number of admissions per day and the resulting large number of transfers after 18:00.

The final research question found out how improvements could be made for the three problems, and what the impact of these improvements are.
The first problem, the late evening visiting rounds at the AAU, are caused by other activities of consultants during the day. Some of these activities, e.g. performing surgery or working in outpatient clinic, have the risk of taking longer than anticipated. This has caused the late evening rounds and its high variation in starting time. The problem can be reduced when the planning of consultants, who do the AAU visiting rounds, is reviewed carefully. Other activities' influence on the start time of the evening visiting round should be prevented as much as possible. This could mean that prior to the visiting round, no such activities should be carried out by the AAU responsible consultant, or the activities should be stopped earlier.
The bad connection of the 8:00 lab round with the morning visiting round, can be improved greatly when there is more time between both activities. The best option for this is to advance the lab rounds with one hour, so enough time is available to process the lab samples. This would mean that lab personnel should start earlier and AAU personnel should possibly gather the samples. Another small improvement could be achieved, when the starting time of the different lab rounds are taken into account. Analysis of the starting time of visiting rounds has revealed that for instance ACH doctors start their visiting rounds most of the time prior to INT doctors. So priority could be given to ACH lab tests over INT lab tests in the morning to increase the number of test performed in time. Both solutions require dedication of the AAU and the lab, so agreements must be made, which solution is best, and how this plays out in practice.
For the final problem, lack of insight in the number of admissions per day, also a design has been made. A method was found to predict the number of admissions per day at the AAU. For each day of week a different prediction was made, since there are large differences in the inflow of patients per day of the week. The optimal number of 'number of admissions' to reckon with, could not be found, since the cost for releasing too many or too few beds could not be determined. Therefore several values were calculated which the AAU can use to determine the number of beds to make available, to limit the number of transfers after 18:00.

All in all this report has shown that the AAU performs well, but improvements are still desirable. Many practical improvements have already been made at the AAU in the last months, but now several structural improvements need to be made as well. When these structural improvements have been made MMC can fully utilize the benefits of having an AAU.

Preface

This report describes the final project I performed to end my study Operation Management and Logistics at Eindhoven University of Technology. The study was performed at the Acute Admissions Unit of Máxima Medical Centre, location Veldhoven. Before you can all read about my findings I would like to thank several people who have aided tremendously in making this master thesis possible.

First of all I would like to thank Monique Jansen-Vullers, my first TU/e supervisor, for her support throughout the project. She always made time to meet and gave useful criticism. Furthermore she really helped me in structuring the report and to shorten the report properly. I would also like to thank my second supervisor, Nico Dellaert, for his useful suggestions for the different designs and comments on my report.

Apart from my TU/e supervisors I would also like to thank my company supervisor Leo Verhagen. He always provided me with useful advice during our meetings. His practical experience helped me a lot in getting things done in the hospital and made the project very instructive.

At the MMC there are many people I would like to thank for their contribution and effort for my project. Michela Zanetti, unit head of the AAU, and Ad Vaarties, business manager of the acute care, where always curios to know what the new figures and analyses showed, which made my work worthwhile. They also made sure not to forget the processes behind the numbers, and provided me with the needed understanding. Furthermore, I would like to thank Agnes van ‘t Hof for her support in gathering the data and the discussions on the meaning of the data. I would also like to thank all the employees of the AAU, you made me feel welcome at the MMC. Also the doctors who were assigned to the AAU helped to enjoy the long hours behind the PC at the MMC. Next, I would like to thank all the people who gathered the much-needed data, and who supplied understanding of the processes behind the data.

Finally, I would like to thank my family and friends for their support throughout my study. Especially the late night discussion with “de jongens” made me see the need for industrial engineers.

Bob Diepeveen
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1 Background

The first section of the report will give a general description of the organization where this master thesis project has been performed. Furthermore the care group and department, at which the project is carried out, are introduced.

1.1 General description Máxima Medical Centre

Máxima Medical Centre (MMC) is a general training college hospital that originates from a merger in 2002 of Deaconesses Hospital Eindhoven and the Saint Joseph's Hospital Veldhoven. MMC is an innovating and enterprising hospital with top clinical functions. It has a teaching qualification for twelve (clinical) specialists. MMC has two sites, one in Eindhoven (EHV) and one in Veldhoven (VHV). The site in EHV focuses on planned admissions, day care and outpatient visits, whereas the site in VHV focuses on complex often acute care, outpatient visits and several day care treatments.
In the Netherlands there are in total 93 hospital organizations (RIVM, 2008). Since a few years now, rankings are made to see how these hospital organizations perform. One ranking, the hospital top 100, is made by a Dutch daily newspaper called Algemeen Dagblad (Algemeen Dagblad, 2008). Their ranking is based on 26 quality criteria which are set by the Netherlands Health Care Inspectorate. In the ranking of 2008, MMC scored a 25th place. In another hospital comparison executed by a weekly magazine called Elsevier (Elsevier, 2008), MMC scored a "good".
The mission of MMC is represented by several points of focus. The most important focal point is the attention given to patients. With the use of care logistics, MMC offers integrated care for their patients. This means that various specialties are integrated and coordinate their tasks to offer best care for the patient. A more specific application of care logistics will be addressed in the next paragraph.
The second focal point addresses the importance of knowledge and skills of its employees. In a medical environment the knowledge of employees is essential, therefore MMC focuses on safeguarding and promotion of knowledge and skills. Quality is MMC's third focal point. Quality improvement is of paramount importance for the safe and good care of patients. The final focal point is personal care and treatment. MMC has a personal approach to their patients, which guarantees personal care and treatment

Some general figures of MMC from the year 2007 are (MMC, 2008):

- Medical staff: about 200
- Medical specialties: 29
- Employees (FTE): 2375
- Beds: 836
- Admissions: about 2600
- First outpatient visits: about 174.000
- Day care admissions: about 18,000
- Visits to the emergency department: about 41,000
- Budget: about 190 million Euros

The core business of MMC, providing health care for patients, is organized around care groups. The different medical specialties are organized in care groups, who have there own financial responsibility. In the organization chart, see Appendix A, these care groups are to be found on the left side.

1.2 Care logistics

The term care logistics is one that is often used at MMC; it is one of its main focal points. A team of professionals with different backgrounds was set up to investigate care logistics at MMC. One of the problems they had to encounter was the lack of synergetic effects of the two locations after the merger in 2002. The team came up with a new care logistical model, which included a totally new location plan. The points of departure of this care logistics model are:

- Triage and treatment plan on both locations;
- Separation of the acute, urgent, predictable and chronic care
- Predictable care per care group is separated based on the prognosis of complex or non-complex care

One of the outcomes of the care logistics model was a change of the location profiles. As of 1 September 2008 EHV is the place to be for planned admissions, day care and outpatient visits, whereas the site in VHV focuses on complex (often acute) care, outpatient visits and several day care treatments. These changes had major effects on the blue prints of both locations, but also for personnel at both locations. On 1 September 2008, the day on which the largest change was implemented; MMC became a new hospital.

One care group within MMC that needed to change greatly is the acute care group. This care group is intended to deal with patients with a broad spectrum of illnesses and injuries, some of which may be life-threatening and requiring immediate attention. The acute care consists of an Emergency Department (ED) and an Acute Admissions Unit (AAU). The patients who come to the acute care of MMC are often first seen at the ED. Here the patient's initial diagnosis is determined and possibly treatment is given. When further diagnosis, treatment and/or observation is needed, the patient is transferred to the AAU.

The AAU is a ward with 32 beds and serves as an intermediate ward between the ED and regular wards in MMC. At the AAU medical expertise is concentrated and fast access to diagnostic tests is available. The AAU is different from normal wards in the sense that it is an intermediate ward; the length of stay is prohibited to 48 hours. Within 48 hours the patients needs to be discharged or admitted to one of the other (normal) wards of MMC. Another difference with a normal ward is that patients from all medical specialties are admitted to the AAU.

One of the benefits of having an AAU is that all acute admissions transform into planned admissions when are admitted at other wards. The best possible ward is found for patients to continue their stay at the MMC, when needed. Another advantage of the AAU is the fast access to diagnostic tests which permits a reduction in length of stay. Finally, the AAU ensures that acute patients are concentrated at one location. Acute patients often require consultation of more than one specialty, since all specialties are represented at the AAU interdisciplinary consultation is possible. More details about the precise functioning of the AAU and the relation with other departments will be provided later in this report.

1.3 Problem definition

After introducing the organization, in which this master thesis project is performed, a description of the business problem will be given. First the business problem is described, after which the research questions are introduced.

The Acute Admissions Unit has been introduced at MMC on September 1, 2008. The AAU was created to provide concentrated medical care to acute patients. Patients at the AAU have faster access to diagnostic tests, and ward rounds are done twice a day. This approach will not only save resources, but more importantly is expected to shorten patients' length of stay at MMC. So patients are burdened less with a hospital stay.

A design was made to determine how the AAU should look like, e.g. how many beds and nurses are needed, and which type of patients should be admitted at the AAU. Due to limited physical space for beds at the AAU, choices were made that restricted certain groups of patients from staying at the AAU. For instance gynaecology patients that arrive at the ED and need to be admitted at MMC are transferred directly to the gynaecology ward. With these measures MMC hopes to assure its intended benefits of having an AAU.

Although the design was made consciously, it remains to be seen if the AAU works as well in practice as on paper. Therefore it is important to reflect upon the performance of the AAU to see if no problems arise. Previous research at AAU's showed several problems (Oddoye et al., 2007; Oddoye et al., 2009). First, the unmatched number of admitted patients to the number of discharged patients causes for delays within AAU's. Additionally, patients who have to wait before they are transferred to other hospital wards cause bed blocking. Bed blocking in turn can prevent new patients from being admitted. This could jeopardize the functioning of the AAU, and limits its robustness. Therefore it is important to analyze the performance of MMC's AAU, and show how the AAU performs. The performance analysis may show that improvements are needed. When this is the case, possible improvements need to be found to ensure the benefits of having the AAU at MMC.

Based on the problem described above the objective of the research is the following:

Develop a model that gives insight in the performance and possible improvements of the processes executed at the acute assessment unit.

This objective leads to the following research question:

What improvements need to be made and/or rules need to be set for the acute assessment unit to ensure a robust system that can ensure its intended performance and benefits?

During preparation of this master thesis the processes at the ED and AAU were closely monitored for a period of six days. During those days the activities of medical personnel were observed. Hereby a clearer view of the processes at these departments could be established. The first impressions at both departments were also food for thought on where possible problems did and could emerge. Now the sub-research questions will be discussed.
First a clear view must be established of the processes at the AAU. What processes are involved in the care, diagnosing and treatment of AAU admitted patients and which professionals are involved in these processes? This will be addressed by answering the first research sub-question:

1. *What are the processes at the AAU?*

When the processes have been described, these processes need to be assessed. A good way to do this is with performance measurement. Which aspects of the performance of the AAU will be assessed and what measure to use will be answered by the following question:

2. *What are the performance measures to assess AAU's performance?*

The main research question addresses the *intended* performance. This means that MMC has their ideas about several performance measures, and how the AAU should score on those. The next research question will deal with this issue:

3. *What is the desired/intended performance of the AAU on the selected performance measures?*

In order to assess the performance, data is needed. The fourth sub-research question will go in more detail about what data is needed, but also how this data can be gathered. Is the data available in databases of MMC or are other data collection methods needed. This leads to the subsequent question:

4. *What data is needed to assess the performance measures and how can this data be gathered?*

When all information to asses the performance of the AAU is available, it is time to assess the performance itself. This will be answered by the fifth sub-research question:

5. *What is the current performance of the AAU on the chosen performance measures?*

The performance analysis of the AAU will show on what measures the AAU scores well and on which measures it performs poorly. These analyses will be the input to find areas of improvement, which will be identified by answering the following research question:

6. *What performance areas of the AAU can, and are necessary to improve?*

Once these performance areas have been identified, several designs need to be found to improve the performance of the AAU. Furthermore these designs need to be tested if they really improve AAU's performance and which design performs best. This results in the following research question:

7. *What improvements need to be made to the AAU to improve its performance, and what impact do these improvements have?*

When all these sub-research questions have been answered, enough information is available to determine which improvements need to be made to ensure a robust system that can ensure its intended performance and benefits. When these improvements have been determined and tested the main research question has been answered.

1.4 Research method

The methodology, used to answer the research question from the previous section, is discussed in this section. The techniques used to answer the research questions and the which actions were taken to validate the outcomes is discussed.

The processes of the AAU have been captured by participating in the process, not as a patient, but by observing nurses. First, the processes at the ED were captured, after that nurses at the AAU were observed. Besides the accompanying of nurses, also internal documents were read to obtain more details on certain processes. The processes were captured in process diagrams and were validated with ED and AAU nurses.

Preceding this master thesis project, a literature study was conducted on performance measurement of health care processes, see Diepeveen (2008). This literature study is the basis for capturing the performance measures to assess AAU's performance. Beside the use of the literature study also other literature sources were consulted to obtain more AAU specific performance measures. The performance measures have been discussed with the supervisors, unit-head of the AAU, and business manager of the acute care. And agreement was reached on the final set of performance measures.

Apart from the settled list of performance measures also desirable performance levels needed to be established. These desired performance levels are based partly on internal documents and partly on consultation with AAU's unit-head and acute care's business manager.

The fourth research question involves data gathering. With the performance measures taken into account, the data sources were established. Data was extracted from information systems used by the inspected departments. The data extracts were discussed with involved personnel to gain insight in the data extracts, and to agree upon the data analysis. On top of this the reliability and validity of the data is checked and discussed with personnell of the AAU, the different contact persons at the other departments, the data providers and data analysers.

The chosen performance measures have been used to assess the performance of the AAU. Different analyses techniques and statistical methods have been used to reflect best on the properties of the processes. The results of the performance analyses were discussed with the supervisors, the unit-head of the AAU, and business manager of the acute care. Hereby specific details of the process were unravelled, i.e. specific causes for the performance were found.

The next research question, *What performance areas of the AAU can, and are necessary to improve?*, follows from the made performance analysis. Industrial Engineering aspects were used to select the problem areas of the AAU. After consultation with my supervisors, the performance areas that are improved in this master thesis project, were established.

Finally, these areas of improvement have been further inspected to see what improvements are to be made. Taking into account the properties of the different processes and the interests of all stakeholders, new solutions were found with the use of statistical techniques, in particular forecasting techniques. These different solutions have also been discussed with the direct stakeholders, and it is up to those stakeholders if these suggested changes are implemented.

1.5 Report outline

The research scheme for the remainder of this report is given in Figure 1.

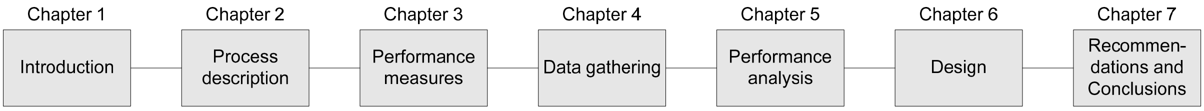

Figure 1: Research scheme

In this first chapter the research has been introduced and the background, objective and research questions have been given. Chapter two will give a description of the processes at and related to the AAU. These descriptions aid to answer the first research question: *what are the processes at the AAU?* In the third chapter, research question two and three will be answered. Literature is used to select the performance measures used in this report and sources within MMC are consulted to formulate the desired/intended performance on the selected performance measures. The data gathering will be described in chapter four. Chapter five shows the performance analysis of the AAU on the introduced performance measures. This performance analysis will also contain a critical review of where the AAU should and could improve. Hereby, both research five and six will be answered in chapter five. Chapter six introduces several designs to improve the performance at the AAU, and will assess the possible improvements gained when using these designs. The report will end with recommendations and a conclusion.

2 Description of processes

Before the processes of the AAU can be analyzed, the processes need to be unravelled first. In this chapter the processes at the AAU will be described. First a general view of the patients flow thought the acute care is given, after that processes at the AAU are described in more detail.

2.1 The acute care group

In this section, the processes that are executed at the acute care are described. The focus in this description is on how the patients flow trough the acute care. The general flow of patients in and out the acute care group is visualized in Figure 2.

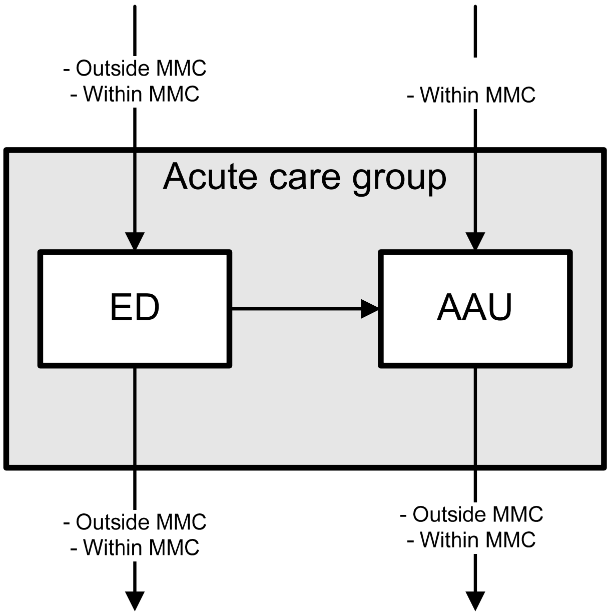

Figure 2: Patient flows at acute care

Most patients, who come to the MMC with acute problems, visit the Emergency Department first. The origin of these patients can vary from outside MMC (self-directed, directed by e.g. a general practitioner, GGD or from within MMC (e.g. one of the outpatient clinics). When a patient has arrived and is registered at the ED desk, the patient is first examined by a nurse to determine the severity of their condition. The severity determines the priority of the patient at the ED. This categorization of patients is called triage.

After triage, and some possible waiting time, the patient is seen at the ED by a nurse and a doctor. Different activities are undertaken to diagnose and possibly treat the patient. A more detailed flow diagram of the internal activities at the ED can be found in Appendix B. After assessment and/or treatment at the ED there are a number of possibilities: the patient is

- admitted to the AAU for further diagnostic tests and/or treatment
- admitted within MMC, e.g. at one of the wards in VHV
- discharged and can leave the MMC

Out of these three options, only patients that are admitted to the AAU, stay at the acute care, see Figure 2, all other patients leave the acute care.

From the patients treated at the AAU about 90 percent come from the ED. The other 10 percent come from other departments within MMC e.g. outpatient clinic, function department or day treatment. During patient's stay at the AAU further diagnostic tests and treatment is given. For details of the processes that take place at the AAU see section 2.2. At the AAU a maximum stay of 48 hours is used, to enforce a high throughput, which is needed for this intermediate ward. After a stay at the AAU the patient is either discharged, because no further immediate care is needed, or admitted at one of the hospitals wards.

2.2 Acute Admissions Unit

At the AAU three different phases can be identified see Figure 3 (the arrows represent the flow of patients): the inflow of patients, patients' stay at the AAU and the outflow of patients. These phases will be discussed separately in the next sections. Note that only the most general way of working is described and exceptions are possible. This way the comprehensibility of the processes is enhanced. Before these detailed descriptions are given, first the reasons to create an AAU in the first place is described and some general facts about the AAU are stated.

The AAU was created at MMC, because of several problems: acute patients stayed too long at the ED, many acute patients were spread over the hospital which limits the possibility of multidisciplinary approach, many patients aren't admitted to the ward of preference, and elective admissions needed to be cancelled. With the formation of the AAU many of these problems should be resolved. Acute patients coming from the ED can be immediately admitted to the AAU, this limits the length of stay at the ED. Acute patients are admitted at one ward, so a multidisciplinary approach for acute patients is enabled. All admissions of acute patients coming from the AAU are planned. This limits the number of miss-placements and the disruptive effects new acute admissions have on wards. Furthermore the existence of an AAU at MMC is expected to decrease the patients' length of stay, which will also reduce the costs. In short the AAU will improve the patients logistics, improves the quality of care under favourable financial conditions.

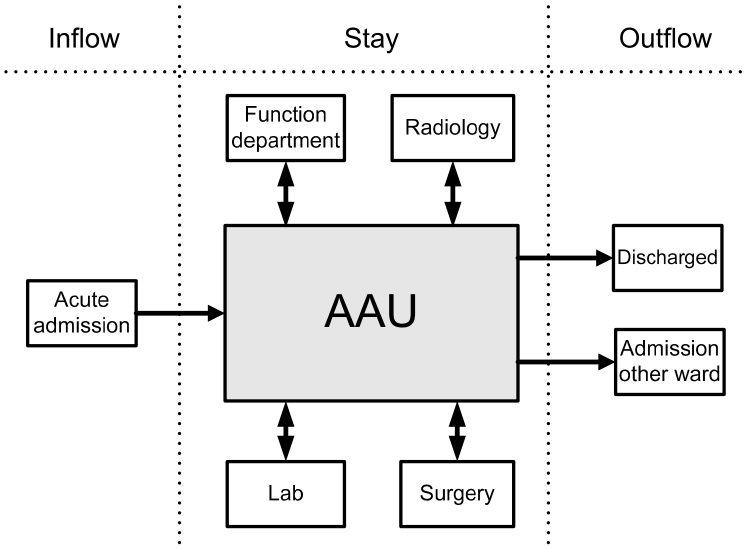

Figure 3: Flow of patients at AAU

The AAU of MMC has 16 rooms which contain 32 beds, see Appendix C for a blue print. Eight of the rooms contain only one bed; these rooms are reserved for patients whose condition calls for a private room. Of these private rooms, 2 rooms are equipped to deal with isolation e.g. for MRSA[1] suspected patients. Beside the private rooms, there are also four rooms with two beds and four rooms with four beds.

At the AAU two units have been made to deal with patients from different specialties. Rooms 1.33 to 1.40 represent unit one and are kept for internal medicine patient. Unit two consist of rooms 1.41 to 1.48 which are kept for surgical patients. This distinction is only indicative, when needed internal patients can also be treated at unit two and the same goes for surgical patients, they can also stay at unit 1. Furthermore, patients from almost all specialties can stay at the AAU so a mix off specialties will always be present.

As discussed in the problem definition, choices were made in the design of the AAU concerning the inflow of patients. Patients from several specialties are not admitted to the AAU, because the AAU

[1] MRSA (Methicillin-Resistant Staphylococcus Aureus) is a bacterium responsible for difficult-to-treat infections in humans (Wikipedia, 2008) and is also called hospital bacterium

does not have appropriate facilities and equipment to guarantee the best possible care. This applies to patients from the following specialties:

- Cardiology
- Gynaecology
- Paediatrics
- Psychiatry

Beside the patient's exclusion form the AAU based on treating specialty, also other acute patients are not admitted to the AAU. This applies to patients who need more specialized care; they can receive this on the following units:

- CCU (Coronary Care Unit)
- MCU (Medium Care Unit)
- ICU (Intensive Care Unit)
- Stroke Unit

Finally there is the group of patients who are not admitted to the AAU, because they are better of at another ward. This applies to terminal patients, for whom it is better to be directly admitted to the ward of their medical specialty. These patients can receive the best care, from medical staff they are acquainted with.

Now the processes that take place during the different phases (inflow, stay and outflow) are described in more detail.

2.2.1 Inflow phase

The processes that take place during the inflow phase at the AAU are visualized in Figure 4. In this figure the diamond shape represents a decision, the rectangles represent the processes, and the arrows represent the sequence in which these processes are executed. In this paragraph, these processes will be further discussed.

The inflow of patients takes place 24 hours a day 7 days a week. At any time of the day, the AAU must be ready to accept incoming patients. The patients come from inside MMC, from either the ED, day treatment, outpatient clinic or the function department. If a doctor decides to admit an acute patient, the AAU is informed by the department of origin that a patient is to be admitted at the AAU. The patient is introduced by phone, and also introduced digitally in CS-EZIS (Electronic Healthcare Information System (Dutch: "Elektronisch Ziekenhuis Informatie Systeem"), see ChipSoft (2008) for further information about CS-EZIS).

Then after some time, the patient is physically transferred to the AAU. It depends on the condition of the patient and place of origin, whether the patient is accompanied by nurses, by patient transport staff, by family, or by no one at all. After arrival at the AAU, the patient is placed at one of the rooms of the AAU. From this moment on, also the digital records in CS-EZIS will reflect to which room the patient is admitted.

When the new patient is accompanied to the AAU by nurses, the nurse(s) from the department of origin and the nurse(s) from the AAU will transfer the patient. During this transfer, medical information of the patient is exchanged. After the transfer, the patient is the responsibility of the AAU and the patients' stay at the AAU has started.

The processes that are executed during patients' stay at the AAU are described in the next section.

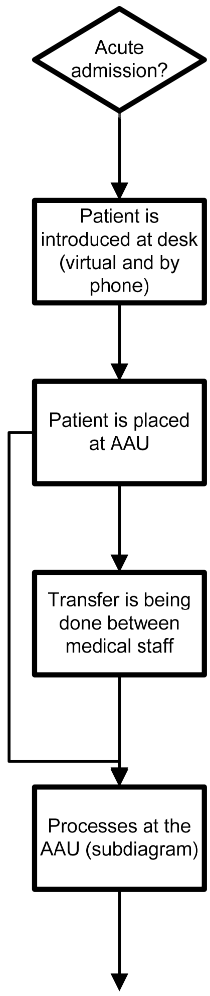

Figure 4: Processes of inflow phase

2.2.2 Stay phase

When the patients have arrived at the AAU many different processes are executed, by just as much or even more professionals. During patients' stay at the AAU, nurses provide the necessary care, and doctors decide on additional diagnostic tests and treatment. Furthermore the laboratory (lab), radiology department, function department and Operation Room (OR) perform diagnostic tests and treatment for AAU patients. All these parties and professionals have an influence on the patients' stay at the AAU; they all affect the performance of the AAU. For instance when a patient can be discharged at the AAU subject to a certain lab level, but the analysis of the sample takes longer than anticipated, the patients' length of stay is influenced. Later in this report when the performance of the AAU is considered all relevant aspects need to be taken in to account. Therefore not only the processes at the AAU are described here, but also the processes that have an influence on the performance of the AAU are assessed.

The processes during the stay phase are not as straightforward as the processes of the inflow phase. There is no sequence or predetermined plan, by which all activities are executed. Furthermore not all tests need to be performed with the all patients. This undermines a clear and detailed graphical representation. Consequently, no patient flow diagram has been used to graphically represent all processes. The diagram used, is displayed in Appendix D. It contains separate 'swimming lanes' for each type of process. Furthermore, as discussed, not all activities and or processes need to be carried out for each patient.

The processes have been grouped by actors and commonality of the processes. The following six groups were made:

- Nurses
- Doctors
- Lab
- Radiology
- Function department
- Surgery

In Appendix D the groups are displayed in columns. Every column displays the processes that are done by a specific group. The figure is based upon the evening shift of the nurses (15:00-23:15) and can be read from top to bottom, where the top is the beginning of the shift and the bottom is the end of the shift. Note that the time distinction in this figure is only indicative, meaning that the displayed order from top to bottom does not need to resemble the executed sequence of processes in reality. Now the processes executed by the different groups are discussed.

Nurses

Nurses at the AAU work in three shifts, these are (start and end time displayed between brackets):

- day shift (07:00-15:15)
- evening shift (15:00-23:15)
- night shift (23:00-7:15)

As can be seen each shift has an overlap of 15 minutes. These 15 minutes are used to medically transfer the patients from e.g. the day shift to the evening shift. The evening shift starts with reading the nurses chart and assignment lists of the patients who they become responsible for. After this, the morning shift will shortly explain some other specificities concerning their patients, to the evening shift.

When the transfer of shifts is completed, the evening shift starts with their daily care. The daily care encompasses for instance: distribute medicines to patients, perform (if needed) vital checks, and update the nurses chart. Some of those processes need to be performed several times during a shift. Furthermore, nurses accompany doctors when they do the ward rounds. During these rounds the nurse can give the doctors extra information about the patient's condition. In addition the nurses need to be informed about any changes in policy, e.g. changing medication or whether the patient needs to be transferred or stays at the AAU.

Doctors

At the AAU, patients from different medical specialties are treated; therefore doctors from different medical specialties are needed. The doctor's task is to evaluate the patient's condition and decide on the treatment plan. During the day there are two key moments at which those decisions are taken, that is with ward rounds. During weekdays the ward rounds are done in the morning around 9:00 and in the afternoon around 16:00. During the weekend ward rounds are done only once a day. With ward rounds doctors see all their patients. The doctors accompanying these ward rounds are consultants, residents, and interns. During ward rounds they decide upon the patient's treatment plan, which includes answers to the following questions (O'Hare, 2008):

- What diagnostic tests need to be done?
- What treatment has to be given?
- What check-ups need to be carried out by nurses?
- When can the patient be discharged or transferred?
- What extra consults (from other specialties) are needed?

All questions are answered, but it is possible that the answer to a question is 'none', for instance when no diagnostic tests need to be done. During and possibly after ward rounds, the medical records of patients are updated by doctors. All the needed paperwork is filled out and telephone calls are made to request diagnostic tests and/or treatment.

During other hours of the day, doctors are still available for the patients, if for instance, new patients are admitted to the AAU, or if a patients' condition becomes worse, doctors will be available to determine and/or adjust the patients' treatment plan.

One of the questions above, '*When can the patient be discharged or transferred?',* has a direct effect on the outflow of patients. The options the doctor has are summarized in the following points:

- keep the patient under observation at the AAU; there is a chance that the patient can go home within 48 hours after admission at the AAU
- transfer the patient to another ward; the patient isn't likely to get better within 48 hours after admission at the AAU, or the 48 hours after admission at the AAU have passed
- discharge the patient; the patient may leave the hospital

The decision to keep, transfer or discharge a patient is made by the doctor at ward rounds.

Lab

A laboratory test is one of the diagnostic tests that can be performed while the patient is admitted at the AAU. For most lab test, blood is drawn and researched in the laboratory. During the day there are four organized moments at which blood is drawn: at 8:00, 11:00, 14:30 and 20:00. After blood has been drawn, it is analyzed in the lab and results are processed. When the lab results are known, they are registered in a computer program called Labosys (see LaboSoftware (2008) for further information about Labosys). Then the results are also automatically transferred to CS-EZIS, this way all medical personnel can access the results.

For other lab tests another type of sample is needed, e.g. faeces, urine or sputum. These are collected by nurses, when they are available. The analysis and processing of the results is done in the same manner as with the blood tests.

Radiology and function tests

The radiology and function tests are discussed here in together since the processes are of the two are very similar. The performed test at the radiology and function department do deviate much, at the radiology department tests like, CT-scan and X-ray photo's are conducted and at the function department, tests like endoscopy are done. Although they also share certain properties:

- The tests are conducted during the day,
- An appointment is made at what time the patient can take the test.

This is why these tests are discussed together in this paragraph.

When a test is requested by the doctor the appropriate forms are filled out. Beside this also a telephone call is made to the department where the test is performed to inform them that a patient of the AAU needs a certain test. After that the desk of the AAU is called when the patient can come for this test. Then, the patient is transported to the test's department, generally by patient transport. When the test is performed, the patient is sent back to the AAU, again with patient transport. Sometimes, it

is also possible that the test is done at the AAU, for instance when the patient, for medical reasons, is difficult to transport.
When the test has been performed a doctor needs to validate the test, and determine what conclusions can be drawn. The conclusions are recorded in an electronic document and when needed, the results are also consulted by phone with the applicant doctor of the test. The electronic document can be accessed in CS-EZIS. The direct results of the radiology test itself, e.g. the X-ray photo, can be viewed in an intranet application and is accessible to medical personnel.

Surgery
The last column in Appendix D displays the processes for surgery. If a patient needs surgery the patient's doctor checks with the OR planning at what time the surgery can be performed. When the patient can come to the OR for surgery, the patient is transported by nurses or patient transport to the OR. Then the surgery can be performed. After surgery, the patient is transported back to the AAU, again by nurses or patient transport.

2.2.3 Outflow of patients

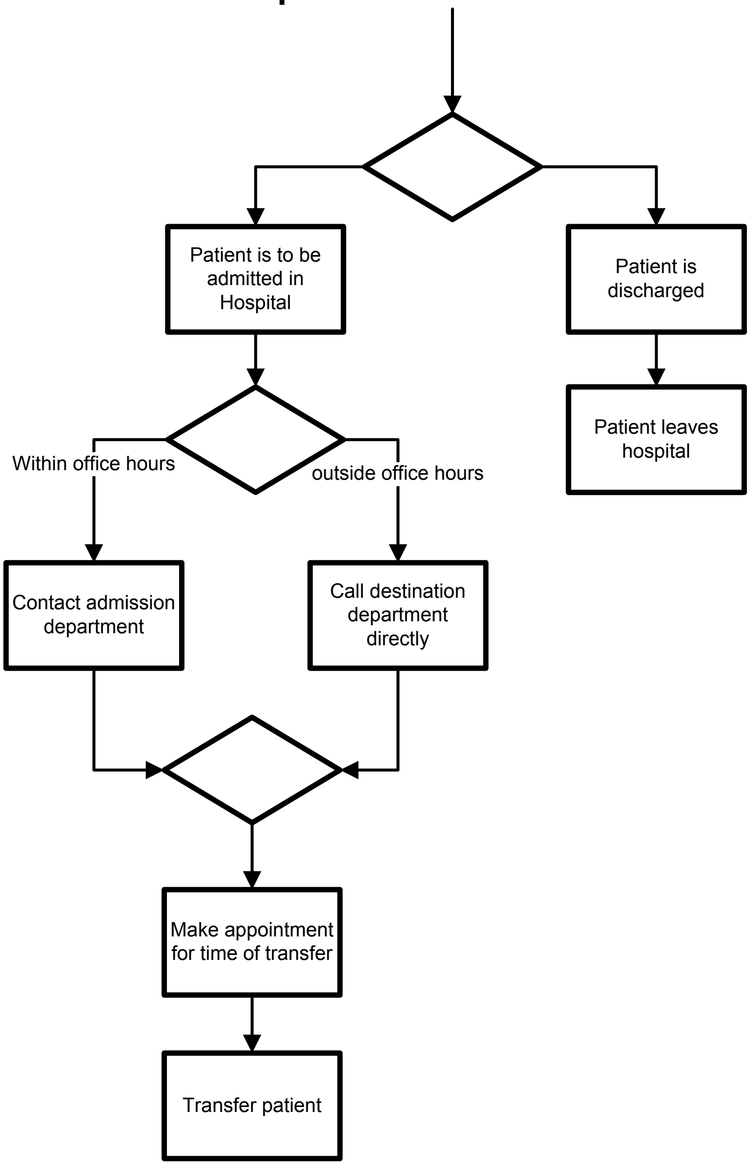

Figure 5: Processes of outflow phase

When the patients' stay at the AAU has ended the outflow phase of patients starts. Actually this phase already starts when the patient is still at the AAU, but all activities described here have to do with the outflow of patients. The processes that take place in this phase are shown in Figure 5.
First, the doctors make the decision: transfer or discharge the patient. If the patient is discharged the patient can leave the hospital. If the patient needs to be admitted at another ward in MMC, it depends on the hour of the day what the routing is. During 9:00-18:00 the admission department decides to which ward the patient is transferred, outside these hours the AAU calls directly to a preferred ward to see if beds are available.
When a destination has been found, the nurses of the AAU and the destination ward decide upon a desired transfer time. An appointment is made for the time of transfer. At that time the patient is transferred to the other ward, either by nurses of the AAU or by nurses from the destination ward.

Based on the processes for inflow, stay and outflow of patients, the next chapter discusses the performance measures to evaluate AAU's performance.

3 Performance measures

Now all relevant processes have been introduced, it is important to reflect on how these processes can be evaluated. The performance measures used in this report are based on the performance measures from the earlier made literature study (Diepeveen, 2008). Furthermore additional measures are also introduced. The main problem under consideration was introduced in section 1.3: the lack of insight in the performance of the AAU, and if and how the performance can be improved. Several performance indicators are introduced that give insight in the performance of the AAU and its related departments.
This chapter is organized as follows, first the variables are introduced to formalize the time moments, needed to create the performance measures. After that, performance measures of the literature study and other literature sources are introduced to analyse AAU's performance. Third, the performance measures used in the MMC are explained. Not only the performance measures are introduced, but for several measures also objectives are set. Finally, all performance measures that are used in this report are summarized.

3.1 Variables

Before the performance indicators are described, it is important to first establish variables. The variables are introduced to make the calculations for the performance measures possible and unambiguous. Some variables won't have meaning yet, but they will when the performance measures are introduced
It is important with the analyses to keep all unique records apart, e.g. the start and end time of an admission needs to be linked to one single patient. Therefore indices were made for the admission number, task type and task. The first index is the admission number, indicated with the letter j. With every admission the patient gets a unique number assigned: an admission number. The admission number is used to link all variables of the same admission. The task type is the second index, specified by the letter i. In section 2.2.2, all processes were described that take place during patients' stay at the AAU, for instance a blood test, a CT-scan, or surgery. Every task type has its own number assigned, e.g. a CT-scan has another number as an X-thorax photo. The last index that is used for the variables is the letter k; it is used to indicate the task number. The task number represents the number of times a specific type of task is done. During an admission it is likely that more than once a specific task is performed, think of for instance a specific blood test e.g. a Haemoglobin test. In order to keep a distinction between the parameters for the same type of task of the same admission the task number is used. Thus when for instance for the fourth time a specific blood test is done during the same admission, the task number is equal to 4. The list below shows all variables used.

AN_j := notice time of start stay at AAU of admission j
AS_j := start time of stay at AAU of admission j
AD_j := decision time of end stay at AAU of admission j
AR_j := result time of time planned transfer known at AAU of admission j
AP_j := planned time of transfer at AAU of admission j
AE_j := end time of stay at AAU of admission j
ES_j := start time of stay at ED of admission j
HS_j := start time of stay in hospital of admission j
HE_j := end time of stay in hospital of admission j
$TN_{i,j,k}$:= notice time of task number k of task type i of admission j
$TP_{i,j,k}$:= planned time of task number k of task type i of admission j
$TS_{i,j,k}$:= start time of task number k of task type i of admission j
$TE_{i,j,k}$:= end time of task number k of task type i of admission j
$TR_{i,j,k}$:= result time of task number k of task type i of admission j
$HR_{s,d}$:= start time of ward round of specialty s at day d
S_j := specialty of admission j
$NB(t_1, t_2]$:= number of beds during time $(t_1, t_2]$, with $(t_1, t_2] = \{x \mid t_1 < x \leq t_2\}$
NN_t := number of nurses working at time t

$NA(t_1, t_2]$:= number of admissions during time $(t_1, t_2]$, with $(t_1, t_2] = \{x \mid t_1 < x \leq t_2\}$
$ND(t_1, t_2]$:= number of discharges during time $(t_1, t_2]$, with $(t_1, t_2] = \{x \mid t_1 < x \leq t_2\}$
$UB(t_1, t_2]$:= average bed utilization during time $(t_1, t_2]$, with $(t_1, t_2] = \{x \mid t_1 < x \leq t_2\}$
$UN(t_1, t_2]$:= average nurse utilization during time $(t_1, t_2]$, with $(t_1, t_2] = \{x \mid t_1 < x \leq t_2\}$
WL := workload norm: number nurses per admission j
$R(t_1, t_2]$:= admission/discharge ratio during time $(t_1, t_2]$, with $(t_1, t_2] = \{x \mid t_1 < x \leq t_2\}$

3.2 Performance measures from literature

The performance measures have been categorized in five dimensions: time, costs, flexibility, internal quality and external quality. The categorization is based on the dimensions introduced in the literature study (Diepeveen, 2008). In this literature study a framework was built to evaluate the performance of (general) health care processes. The focus in the literature study was to create performance measures that can be used in simulation studies. The mentioned five dimensions in the framework were 'filled' with performance measures. With the use of the literature framework a comprehensive performance analysis of health care processes is possible.
The literature study focused on general hospital processes, whereas here an AAU is inspected. This suggests that more specific performance measures regarding AAU's are needed (Diepeveen, 2008). For this reason, not only the performance measures from the literature study (Diepeveen, 2008) are used, but also other literature sources are inspected, to find the most relevant and practical performance measurements.
Since only a limited number of articles has been written on the subject of AAU from an industrial engineering point of view (Oddoye et al. 2007, 2009), it is not clear which aspects relating an AAU are best to analyse. Therefore a broad spectrum of performance measures is used here to assess AAU's performance. Most performance measures from the literature study have been used, at least for the time dimension. Furthermore, problems described in Oddoye et al. (2007, 2009) have hinted for the use of several other performance measures.
The next four subsections are used to describe the performance measures per dimension. First, the performance measures of the time dimension are described, then the cost dimension, after that the flexibility dimension is presented and finally the quality measures are introduced.

3.2.1 Time measures

In this section the performance measures of the time dimension are discussed. The different performance measures that are used for the time dimension are summarized in Table 1. Also, the relation of several variables with the time measures has been visualized in Figure 6 and Figure 7.
As can be seen in Table 1 there are many different time measures, which guarantees a detailed level of analysis. This allows for a quick indication where in the process the problems are. When only a global analysis is made, one cannot grasp the precise cause for a possible delay. Therefore the access time, length of stay (LoS), and throughput time have been divided into several different measures.

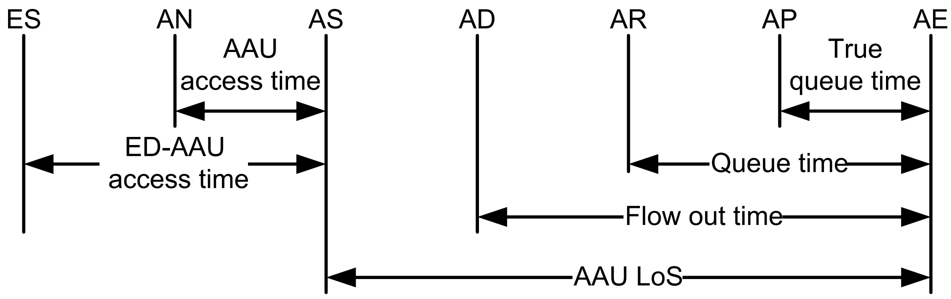

Figure 6: Visualization of the AAU time performance measures

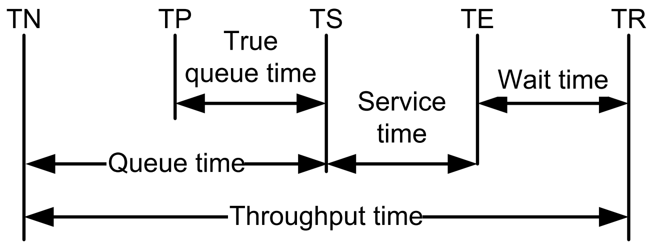

Figure 7: Visualization of the task time performance measures

Table 1: Time performance measures

Name	Description	Calculation
AAU access time	the time it takes after a patient is presented at the AAU	AS_i - AN_i
ED-AAU access time	the time it takes from seen at the ED to when a patient is presented at the AAU	AS_i - ES_i
AAU LoS	the time during which a patient is admitted at the AAU	AE_j - AS_j
Hospital LoS	the total time a patient is admitted at MMC	HE_j - HS_j
Hospital LoS after AAU transfer	the time a patient is admitted to the hospital after staying at the AAU	HE_j - AE_j
Hospital LoS from AAU admission	the time a patients is admitted to the hospital from the time of AAU admission	HE_j - AS_j
Flow out time	The time during which the transfer or discharge of a patient is arranged	AE_i - AD_i
Queue time	The time a patient has to wait in the queue before a task can start.	AE_i - AR_i $TS_{i,j,k}$ - $TN_{i,j,k}$
True queue time	The time the patient has to wait in the queue before a task can start, from the time the task was planned to start.	$\max\left[0,\left(AE_j - AP_j\right)\right]$ $\max\left[0,\left(TS_{i,j,k} - TP_{i,j,k}\right)\right]$
Service time	the time a resources spent on actually diagnosing or treating a patient	$TE_{i,j,k}$ - $TS_{i,j,k}$
Wait time	all other delays for a patient, e.g. the time a patient has to wait before the results of a test are available	$TR_{i,j,k}$ - $TE_{i,j,k}$
Throughput time	the time between the notice time of a task and the completion of that task	$TR_{i,j,k}$ - $TN_{i,j,k}$
Tardiness	the time a result of a test is too late in relation to the ward round	$\max\left[0,\left(TR_{i,j,k} - HRS_{s,d}\right)\right]$

3.2.2 Cost measures

In contrast to the time measures, only few of the cost measures found in Diepeveen (2008) are used here. Many of the cost measures aren't applicable to the AAU, think of machinery running costs. Other costs do not change during the inspected time period, like nurses utilization and have also not been used here. In total three performance measures are described here: bed utilization, nurse utilization and inflow/outflow ratio. Both utilization measures can be found in Diepeveen (2008), the inflow/outflow ratio is based on Oddoye et al. (2009).

The first performance measure is the bed utilization and is calculated in the following manner:

$$\text{if } AE_j > t_1 : \quad \text{if } AS_j < t_2 : \quad UB(t_1, t_2] = \frac{\sum_{j=0}^{\infty}\left\{\min\left[AE_j, t_2\right] - \max\left[AS_j, t_1\right]\right\}}{NB(t_1, t_2] * (t_2 - t_1)}$$

The bed utilization is calculated for a period ranging from t_1 to t_2. The LoS is determined for the admissions that are present at the AAU during the researched time period. It is safeguarded that the start time is not earlier then t_1 and the end time not later then t_2, this way the real bed utilization during the time period can be determined. The sum of the LoS of all admissions during these time periods, is divided by the time the number of beds are present during the same time period. Note that this calculation makes it possible for the number of beds to change during the researched time period.
The nurse utilization is the second cost measure and is calculated in almost the same way as the bed utilization. The total workload for nurses is calculated by multiplying the sum of the LoS of all admissions during the determined time period, by the nurse workload. When this number is divided by the number of nurses present at the AAU during the time period the nurse utilization is calculated. This nurse utilization is calculated by:

$$\text{if } AE_j > t_1: \quad \text{if } AS_j < t_2: \quad UN(t_1,t_2] = \frac{\left(\sum_{j=0}^{\infty}\left\{\min\left[AE_j, t_2\right] - \max\left[AS_j, t_1\right]\right\}\right) * WL}{\sum_{t=t_1}^{t_2} NN_t}$$

In this formula the nurses workload norm is used, this norm is however not that simple to calculate. Morris et al. (2007) show that the nursing workload is determined by three components: direct patient care activities, indirect patient care activities and non-patient care-related activities. Of these three components, the first two are most affected by the admissions. The amount of direct and indirect patient care is dependent on the complexity of skill mix, time taken to carry out nursing work, patient dependency and severity of patient illness Morris et al. (2007). Since the AAU accepts acute patients whose severity can vary greatly, no specific workload calculations have been made. Only a constant number could be derived with the help of Van de Heede et al. (2008). However, since the number of nurses working at the AAU does not change over time and the best nurses' workload factor approximation is constant, the nurses workload calculation is not different from the bed utilization calculation. Therefore, in the remainder of this report the nurses' utilization is assessed with the use of the bed utilization.
As discussed in the problem definition (section 1.3) an unmatched number of admitted patients to the number of discharged patients cause delays within AAU's (Oddoye et al., 2009). Therefore, the next performance measure, calculates the ratio of the number of admissions, to the number of outflows per time period. This performance measures shows if the population at the AAU is rising or decreasing in a certain time period. The calculations made are as follows:

$$\text{if } t_1 \le AS_j < t_2: \qquad NA(t_1,t_2] = \sum_{j=0}^{\infty} \frac{AS_j}{AS_j}$$

$$\text{if } t_1 \le AE_j < t_2: \qquad ND(t_1,t_2] = \sum_{j=0}^{\infty} \frac{AE_j}{AE_j}$$

$$R(t_1,t_2] = \frac{NA(t_1,t_2]}{ND(t_1,t_2]}$$

First the number of admissions and discharges during the determined time period are established, after that the ratio is determined.

3.2.3 Flexibility measures

Flexibility is the third dimension for which performance measures have been made. The performance measures used in Diepeveen (2008) are mix flexibility, volume flexibility, labour flexibility and routing flexibility. None of these four flexibility measures are used in this report. The reasons for this will be assessed below

.

Mix flexibility has already been discussed in the problem definition (section 1.3): not all patients can be admitted to the AAU. The mix flexibility does not change in the investigated period, therefore the mix flexibility measure is not used.

The second type of flexibility is volume flexibility. Because the volume of patients the AAU can handle, is equal to the number of beds used. And because the number of beds is fixed, the volume flexibility is equal to the bed utilization. Therefore no new performance measure is introduced.
Labour flexibility is also omitted from the performance measures, since all nurses can perform the same tasks. And since nurses all receive a specific AAU education, they are all skilled to do their job.
The last flexibility measure is routing flexibility. Routing flexibility is not present at the AAU, since all acute patients need to be admitted to the AAU, there are no other possible routings. Therefore this measure is not used either in this report

3.2.4 Quality measures

In this section the performance measures for both quality dimensions, internal and external, are discussed. First the internal quality measures are discussed, then the external quality measures are discussed.
Most of the internal quality measures introduced in Diepeveen (2008) are not used here. There are several reasons for doing so:

- Many performance measures do not change over time
- Some measures are out of scope
- Much data needed for the quality measures isn't available or attainable

The only relevant and applicable internal quality measure is a measure that is already discussed with the time measures. The last time measure, tardiness: *the time a result of a test is too late in relation to the ward round* is not only a time measure, but also a quality measure. The quality of the medical decision is likely to increase, when all requested information is available at the time the decision is made. Since the measure is already introduced with the time measures, it does not need be introduced again.
In Diepeveen (2008) was found that no new measures for external quality, needed to be introduced, all relevant performance aspects are already covered by other measures of other dimensions. For instance queuing time is related to patient dissatisfaction (Sitzia & Wood, 1997). Since all other dimensions have been already discussed no more new performance measures are introduced for the external quality dimension.

3.3 Performance measures and target levels used in MMC

When the design for the Acute Assessment Unit was made, MMC set several targets for the performance of several measures. In this chapter these targets levels are introduced. These targets have been set to safeguard the robustness of the AAU. When the targets are attained it is very likely that the AAU performs well.
The first target set, is one that takes place just before the AAU, at the ED. At the ED a target level is set for the maximum LoS at the ED. Patients at the ED should leave the ED within 3 hours. This enforces ED nurses and doctors to evaluate the medical condition of the patient fast, and discharge or transfer the patient quick. Because of the AAU a fast outflow of acute, to be admitted, patients safeguarded. In terms of this report the *ED-AAU access time* should be less than 3 hours; otherwise patients stay too long at the ED.
The second performance measure that is discussed here is the *AAU Los*. As is discussed earlier the maximum stay at the AAU is 48 hours. One has to note that this target isn't fixed. The target level that is set by the MMC is that 80% of the patients should have left the AAU within 48 hours. After 48 hours the patients need to be either discharged or admitted at another ward. Thus the *AAU LoS* of the patients should in 80% of the cases be smaller than 48 hours.
The hospital LoS is associated to the third target level. For this target level, the cumulative discharge percentage for AAU admissions per specialty is set. In Table 2 the target levels are shown per medical specialty. Note that this table does not refer to the hospital Los, but to the hospital LoS from AAU. For instance 30% of the INT patients should be discharged within 48 hours, and 75% of the INT patients should be discharged within 10 days.
MMC believes that because of the introduction of the AAU not only the percentage of acute patients that can be discharged within 48 hours (during patients stay at the AAU) is increased, but also the patients that are admitted at other wards in MMC can be discharged earlier. MMC expects that the

hospital LoS of all acute patients is shortened, because of the faster diagnosis and treatment within the first two days of their stay.

Table 2: Cumulative discharge target percentages of AAU patients per specialty

Specialty of admission	Day 1	Day 2	Days 3-5	Days 6-10	Days 11-16	Days 17-30	Days 31 - 99	More than 100 days
ACH	20%	50%	65%	85%	92%	97%	100%	100%
INT	15%	30%	50%	75%	88%	97%	100%	100%
PUL	10%	30%	40%	70%	90%	98%	100%	100%
MDL	10%	30%	55%	80%	90%	97%	100%	100%
ORT	20%	45%	55%	75%	85%	95%	99%	100%
URO	10%	30%	70%	95%	96%	99%	100%	100%

Beside targets for the ED- AAU access time and LoS, also a target is set for one of the diagnostic tasks: Radiology. The AAU has made an agreement with radiology to ensure fast diagnostic possibilities for AAU patients. All results of diagnostic radiology tests for AAU patients should be ready within 24 hours of the notice time. Thus within 24 hours, from the moment the test is requested, the results of the test should be available to the doctors.
With the laboratory department also agreements have been made. These agreements are similar to all agreements made with other ward departments in the MMC. For several tests a service time goal has been set. The tests are normal, urgent and CITO. The agreed service times for these tests are 360, 120 and 45 minutes, respectively. These agreements need to be fulfilled in 95% of the cases.

Most of the performance measures introduced in this chapter will be used in the remainder of this report to assess the performance of the AAU and its related departments. A complete list of all performance measures used can be found below.

In chapter 2 the different processes were described, in this chapter the performance measures to assess these processes are introduced. In the next chapter the data gathering techniques used, needed to assess the AAU's performance, are discussed.

Table 3: Performance measures included in the analysis

Performance measures	Performance measures
AAU access time	True queue time
ED-AAU access time	Service time
AAU LoS	Wait time
Hospital LoS	Throughput time
Hospital LoS after AAU	Tardiness
Hospital LoS from AAU admission	Bed utilization
Queue time	Nurse utilization
True queue time	AAU inflow/outflow ratio

4 Data gathering

In order to assess all performance measures described in the previous chapter many data needs to be available. Without reliable, valid and accessible data the results of the performance analysis will be limited. Therefore in this paragraph more insight is given about data gathering. First some general information about MMC's information systems is given. After that, a more detailed analysis per data source is given. Per data source the method of data collection, the period of which the data is collected, the selection criteria for the data, the reliability, and the validity of the data is discussed. In addition, the different data-fields are matched to the variables described in section 3.1.

At MMC most of the data is recorded with the use of Chipsoft's system CS-EZIS. Beside all patients' personal information e.g. date of birth, also medical information is recorded. Furthermore the system keeps track of the location of the patient, so at what time at which ward the patient is being treated. The general data like LoS and specialty of admission is gathered from CS-EZIS. CS-EZIS has also several extra functionalities in which more specific processes are supported. One of these extra functionalities is CS-OK. CS-OK supports the planning and processes done at the Operation Room (OR). The data concerning surgeries will be obtained from CS-OK. Another extra functionality present in CS-EZIS is CS-SEH. CS-SEH supports the processes and registration at the ED, so the data concerning the ED is gathered from CS-SEH.
Beside the general system: CS-EZIS, several more stand-alone, specialized information systems are in use. The laboratory uses its own information system called Labosys and the radiology department also uses its own information system. Luckily for the users most data stored in the specialized systems can be retrieved with CS-EZIS. CS-EZIS can display for instance the lab results of a lab test and the report of a radiology test. All information in the information systems is linked based on the patient number. With respect to the data gathering for the laboratory and radiology, this data is gathered from these specific information systems. In Appendix F all data overviews are stated in relation to the performance measure variables.
Now the description per data source will follow. First the collection of general data of the AAU and other wards within the MMC are described. After that the detailed data collection for the AAU is explained. Then, subsequently the ED-, laboratory-, radiology-, and surgery-data gathering aspects are explained.

4.1 General data AAU and wards

The general data concerning the AAU and wards at MMC, consist of: time of admission, time of discharge, and medical specialty per admission. CS-EZIS records every change of a patients' admission, for instance when a patient is transferred to another ward. Therefore, many needed time stamps concerning the AAU are recorded. The following variables are recorded in the general data AAU and wards overview: AN_j, AS_j, AE_j, HS_j, HE_j, and S_j.
The time period for this data overview is May 1, 2008, till February 16, 2009. The first three months of data, May, June and July, are used to reflect on the performance of the MMC before the AAU was opened. The following three months, September, October and November, are used to analyse the situation during AAU. The remaining time period, December 1 to February 16, is used to improve the performance of one of the designs made.
The reliability of the data is largely dependent on the accuracy of registration by secretaries. Secretaries (and sometimes nurses) at the departments register the times in CS-EZIS. They admit and discharge the patients digitally. Although the time the patient is digitally admitted or discharged can differ from the real admission or discharge moment, the reliability of the data is not at stake. First of all, the difference in real and digital time will be in the magnitude of minutes, which is relatively small compared to the patients' total stay. Second, CS-EZIS offers the functionality to alter the time of admission or discharge. The validity of the data is not at stake here, in CS-EZIS it is clear that with the digital admission, transfer or discharge these times are recorded. It is clear for employees what these times represent.
Before the data obtained from CS-EZIS is used for analysis, the data is further inspected for errors. Two types of errors were found and were adapted to increase the consistency between the real world

and the digital world. One of the errors that occurred was that several admissions had more than one admission at the AAU. The admission numbers of 17 AAU records were altered. The admissions numbers of those records can be found in Appendix I. The second type of error present in the data, were patients that seemed to be admitted at the AAU, but were never put in an AAU bed. This type of error was repaired by deleting the AAU records of these 26 patients, the admission numbers are also described in Appendix I.

4.2 Detailed data AAU

Not all variables, needed to assess all performance measures of the AAU, are registered by CS-EZIS. Several detailed variables needed to be gathered in another way. These variables are: AD_j, AP_j, AR_j, and $HR_{s,d}$. It was decided, after confer with the unit-head of the AAU and with the MMC supervisor of this project, that this data was going to be recorded by hand with the help of AAU nurses. Forms were made to simplify the recording of data and reduce the effort needed from nurses as much as possible. In Appendix G these forms are displayed. The first two pages of this appendix contain the forms to record $HR_{s,d}$. In these forms, the time a visiting round of a specific specialty was started and also if the consultant (Dutch: ”Hoofdbehandelaar”) accompanied the visiting round was recorded. On the third page of Appendix G the form is displayed that was used to record times AD_j, AP_j and AR_j,.
At the start of each nurses' shift the secretary printed a department occupation overview, see Appendix H for the instructions manual (in Dutch) . The overview was made with the use of the AAU occupation overview in CS-EZIS and a custom made Excel file. During the day, the AD_j, AP_j and AR_j, times are filled out in the overview.
Before the data gathering started, nurses were informed about the data gathering, why the data gathering was needed, and how the forms should be filled out. During each shift one nurse, the so called spot duty (Dutch: 'stip-dienst'), was responsible for filling out the forms. This spot duty rotated between the nurses, almost every shift a different nurse was responsible for the list. In the first two weeks around the start of the morning and evening shift it was verified if the spot duty nurse knew what times needed to be filled out. After these two weeks no extra introduction was given since nearly all nurses has had a spot duty and knew how to fill out the forms. Besides, they had the opportunity to ask me questions, because I was present at the AAU during the day.
The detailed data of the AAU was gathered for just over one month; from October 28, till November 30, 2008. After the data had been gathered it was entered in Excel to enable quick analysis.

4.3 Data ED

Just as the general data of the AAU and wards, the ED data is gathered in CS-EZIS, be it in CS-SEH which is a specialized module. In the data overview from the ED the ES_j variable is used: the start time of stay at the ED. The start of the treatment at the ED was chosen as the ED start time. This time represents the best and most reliable moment of all available time moments. From the ED overview only patients who were admitted to the AAU have been selected. The reliability and validity of the ES_j variable have both been checked, and are both in order.

4.4 Data laboratory

The data of the laboratory was retrieved from Labosys, the information system used at the laboratory. From this overview the following time variables were gathered: $TP_{i,j,k}$, $TS_{i,j,k}$, $TE_{i,j,k}$, and $TR_{i,j,k}$. Note that the notice time, $TN_{i,j,k}$, cannot be gathered from the overview, this time moment isn't gathered. In the future when all lab requests are done digitally, and not on paper, the precise notice time can be gathered.
There is a difference between tests that are done for a lab round, or tests that are done 'klinisch lopend'. The difference between these tests is that for the lab rounds a planned time, $TP_{i,j,k}$, is available, the time of the lab round, and for the 'klinisch lopend' tests not, these are done immediately. For the $TS_{i,j,k}$ one needs to be aware that the start time is not the real start time. The $TS_{i,j,k}$ for the lab is the time when the blood sample is signed into the lab, thus after the sample has been taken. This time differs from the real $TS_{i,j,k}$, the time when the blood is drawn from the patient. However, since this time moment is registered the time when the sample is at the lab will done fine.

The data was gathered from the date the AAU was opened, September first, to November 31, 2008. Only those tests that were requested from the AAU were included. This resulted in an overview which still contained entries that does not represent real lab tests and/or tests that do not apply to the throughput time norms set. The selection of the right lab tests from the lab data overview was put together with the help of a clinical chemist. From a list with all requested types of lab tests, to be included type of lab tests were selected. Only tests equal to one of the selected test codes were analyzed for their performance. The list of included types of tests can be found in Appendix I and the list of excluded type of lab tests can be found in Appendix K. The reliability and validity of the lab data is no issue, since the lab is almost completely computerized. Almost all data is registered automatically with or without the help of employees.

4.5 Data radiology

Data of the Radiology department has been gathered with the use of their information system. An overview was made in which all radiology tests performed, during September 1 till November 30, 2008 for AAU patients. In the data overview the following variables are present: $TN_{i,j,k}$, $TP_{i,j,k}$, $TS_{i,j,k}$, $TE_{i,j,k}$, and $TR_{i,j,k}$. Because of validity reasons the $TP_{i,j,k}$ and $TS_{i,j,k}$ aren't used. The $TP_{i,j,k}$ needs to be filled out with every radiology test, but this isn't always done for AAU patient. The $TS_{i,j,k}$ for radiology tests is also not used. The start time of the tests is recorded, but the time is changed when the tests are billed, therefore the start time does not reflect the real start time. Thus only $TN_{i,j,k}$, $TE_{i,j,k}$, and $TR_{i,j,k}$ are used to analyze the performance of the radiology. Note that the $TN_{i,j,k}$ does not reflect the real notice time of a test i.e. the time at which the doctor requests the test, but represents the time when the request form is scanned at the radiology department..

The overview of radiology tests contained tests that do not represent normal or important tests. Together with a Radiologist and an office manager of the radiology the non-normal or unimportant tests have been identified. Furthermore all radiology tests were coded to sample all comparable tests. These codes were applied to see if there are differences between the throughput time per test. It is very likely that the throughput time of a CT differs from an X-ray photo, because of the longer service time of a CT, and the high work load on a CT-scanner, which is an expensive machine. In Appendix L the codes of the different types of radiology tests can be found. X-ray photos are coded 1, CT scans 2, ultrasonography 3, MRI 4, other tests 5 and unimportant and non-normal tests are coded 9. The tests with a code 5 or 9 are not used to review the performance of the radiology department.

4.6 Data surgery

The data needed to analyse the performance of the surgery department in relation to AAU patients has been obtained from CS-OK. For the period September 1 to November 30, 2008, data was gathered for AAU patients who had a surgery during their stay. The selection was made for patients that had department code AAU as the department of request. The data used from the CS-OK overview includes only $TS_{i,j,k}$ and $TE_{i,j,k}$. Other time moments are either not recorded or not interesting to analyse here. There are many different time moments captured at the surgery department, but these are merely of internal use of the surgical department, but are of no importance with the regard to the relation with the AAU. Surgeries are less standardized then for instance an x-thorax photo, and indications for improvement, if any, are less likely to be found in the detailed surgery data.

The reliability and validity of the data has been checked, and found in order; all data is captured electronically, and it is clear what the different time moments are.

4.7 Data function department

The data obtained for the different function departments is obtained from CS-EZIS. Again the period on which the data is gathered is September 1 to November 30, 2009. Of all data sources the data on the function department is the least detailed. Of the patients of the AAU that are seen at one of the function departments only the specific date is known when this test is done. All time variables, $TN_{i,j,k}$, $TP_{i,j,k}$, $TS_{i,j,k}$, $TE_{i,j,k}$, and $TR_{i,j,k}$ are unavailable for this department. The types of analysis done for the function department will therefore be limited. The reliability and validity of the data is not an issue here, since the day on which the test is performed will always be correct, due to the digital registration.

5 Performance analysis

In previous chapters, the problem at hand was introduced, processes were described, performance measures were set up and the data gathering methods and the quality of the data have been discussed. In this chapter the performance measures listed in section 3.3 will be used to assess the performance of the processes at, and in relation to, the AAU. This will be done with use of the gathered data. First, the situation before AAU and during AAU will be compared; does the AAU have a positive impact on the LoS of acute patients. Then the performance concerning the inflow phase will be discussed. The number of admissions, the specialty of admission and the access time will be subject for debate. Third, all processes during the patients' stay at the AAU are discussed, including not only the processes at the AAU, but also tests which are performed elsewhere in the hospital. After that, the performance and properties of the outflow phase are given. The performance measures that relate to the hospital stay after AAU will be discussed next. This chapter will be concluded with a short summary of all performance analyses and a choice is made, which problems will be addressed in the next chapter. This extensive performance analysis will show, apart from understanding of the characteristics of the processes, on which areas the AAU performance well, and were improvement is possible and/or needed.

5.1 Performance comparison: before AAU, during AAU

The first aspect of the performance analysis is the comparison between the situation before September 1 and the situation after September 1. It is compared if the performance differs before the opening of the AAU and after the opening of the AAU. Hereby an answer can be given to the question, does the AAU improve the performance for acute patients at the MMC.

The comparison between the before AAU and during AAU situation is based on the LoS of acute patients. In the period before AAU it isn't possible to select the patients that would have been admitted to the AAU if such a ward existed. Furthermore, potential patients were first admitted to two locations VHV and EHV, and afterwards only in VHV. The best way to compare the before and during AAU situation is to compare the LoS of acute patients. The subset of acute patients can be filtered even more precise, since patients from certain specialties aren't admitted to the AAU. Several patient groups can be excluded. Furthermore, If only the patient groups from the same medical specialty are compared it can be seen if for patients from that specific specialty the AAU is beneficial. The time period of which the patients' LoS is compared is very important.

Table 4: Patient selection criteria for comparison

Criteria	Before	After
Patient selection	Acute admissions (no selection can be made for AOA patients)	Acute admissions (thus more than only AAU)
Which hospital location	VHV and EHV	Only VHV (no acute admissions at EHV)
Included specialties	ACH, INT, MDL, NEU, ORT, PUL, URO	ACH, INT, MDL, NEU, ORT, PUL, URO
Data gathered during	May, June	September, October
LoS is cut off at	20 days	20 days

First of all, the time periods should be of equal length, therefore a period of two months has been chosen. Second, the months need to be comparable, thus about the same number of admissions should take place during the two months. Of the period before AAU, the months May till July are available. The chosen months for the during AAU period are: September and October. Lastly, in order for the comparison between the months to be fair, one does not want very long LoS's included in the subset. The influence of having an AAU for patients with a very long LoS will be almost negligible. Furthermore, at the time the comparison was made only data till November was available, for a fair comparison the before period should also be cut off artificially. Keeping these two remarks in mind, it

was decided to cut off the LoS at 20 days, so lengths of stay longer than 20 days have been rounded down to 20 days. Hereby the full patients' length stay is still included in 90% of the cases. All details about the comparison have been summarized in Table 4.
The summarized results of the LoS comparison between the before and during AAU period are displayed in Table 5. For all selected specialties together and per specialty, the number of admission, the average LoS and the cumulative LoS distribution fraction is displayed for the before and the after AAU period. Before the results are interpreted it is necessary to first look if the comparison made is valid. Besides the already taken measures, like the cut off LoS, it needs to be checked if the two time periods are similar. One way to check the similarity between periods is to check the number of patients admitted. The total number of acute admission is about the same for both periods. Furthermore the number of elective patients in both periods have been checked, in the before period there were 1468 elective admissions and 1575 in the after period. So the number of elective patients did increase, but increased relatively as much as the number of acute admissions did. This means that a global comparison is possible. The comparison of the two periods, for the specialties separately is done next. Almost all specialties have a similar number of admissions in both periods, only ORT has received more than twice as much patients in the 'during AAU' period. It is therefore for all specialties, except ORT, fair to compare the before and during period.

Table 5: Summary of results patients' LoS comparison

Specialty	Period	n	μ	0-1	1-2	2-5	5-10	10-15	15-30
TOTAL	Before	1287	6.41	0.29	0.44	0.67	0.84	0.90	1.00
	During	1323	5.83	0.31	0.49	0.69	0.85	0.92	1.00
ACH	Before	353	5.84	0.19	0.36	0.64	0.80	0.86	1.00
	During	372	4.80	0.29	0.52	0.70	0.85	0.90	1.00
INT	Before	350	6.86	0.18	0.26	0.51	0.76	0.85	1.00
	During	331	5.89	0.22	0.42	0.58	0.79	0.89	1.00
MDL	Before	137	5.89	0.12	0.26	0.58	0.80	0.92	1.00
	During	130	5.69	0.15	0.40	0.58	0.82	0.90	1.00
NEU	Before	151	6.63	0.26	0.38	0.56	0.75	0.82	1.00
	During	144	6.36	0.22	0.32	0.57	0.76	0.85	1.00
ORT	Before	41	6.59	0.15	0.37	0.54	0.73	0.85	1.00
	During	97	6.88	0.21	0.36	0.51	0.73	0.87	1.00
PUL	Before	175	7.57	0.10	0.17	0.41	0.76	0.84	1.00
	During	156	7.91	0.09	0.21	0.37	0.72	0.83	1.00
URO	Before	80	4.75	0.16	0.34	0.64	0.89	0.96	1.00
	During	93	4.52	0.13	0.39	0.67	0.89	0.97	1.00

The comparison of the before and during AAU period can now be executed for all specialties, except ORT. It depends on the characteristics of the LoS which type of statistical test can be used for the comparison; Dorgé (2008) has been used as directive. Hospital LoS distributions are continuous, given that the LoS is a time-variable which contains an interval of real numbers (Montgomery & Runger, 2003). Most of the time, hospital LoS distributions do not follow a normal distribution, and are non parametric, see Marshall et al. (2005) for a review of different techniques to model the LoS distribution. Here the LoS does not follow either a normal distribution.
Each comparison made here is based on two samples, comparing all admission from before AAU with the period during AAU, or comparing the admissions for a specific specialty between both time periods. To be able to use the Mann-Whitney U test, which is used to compare two nonparametric distributions (Ho, 2006) and evaluate whether the medians differ significantly (Green & Salkind,

2003), both distributions are assumed to have the same shape and spread, and (might) only differ in their locations (Montgomery & Runger, 2003). Since the comparisons are based on patient groups from the same specialty, it is assumed that the distributions have indeed the same shape and spread. In addition to the Mann-Whitney U test, the Kolmogorov-Smirnov test is also used. The Kolmogorov-Smirnov test is a more general test and detects differences in both the location and shape of the distribution (SPPS, 2008). It is possible that the cut of LoS can result in differences in the shape in the distribution, thus the Kolmogorov-Smirnov test is a fine addition to the more popular Mann-Whitney U test (SPPS, 2008). The results of the analyses are summarized in Table 6, the SPSS output can be found in Appendix M.

Table 6: Sample comparison before and during AAU

	Asymptotic significance (2-tailed)	
Days compared	Mann-Whitney U test	Kolmogorov-Smirnov test
TOTAL	0.001	0.000
ACH	0.001	0.000
INT	0.012	0.000
MDL	0.337	0.039
NEU	0.947	0.818
PUL	0.578	0.593
URO	0.576	0.627

From the analysis can be concluded that the hospital LoS of acute admissions in total and for the specialties ACH and INT was smaller during AAU then before AAU, with a significance level of respectively, $p<0.01$, $p<0.01$ and $p<0.05$. The hospital LoS of other specialties was not significant different between the two periods, which was to be expected, based on the average LoS, see Table 5. The significantly reduced LoS during the AAU period implies that the introduction of the AAU has a negative impact on the average LoS of acute patients. The AAU seems beneficial for only the ACH and INT in terms of shortening the average LoS. Although it seems that two out of the seven medical specialties improving their performance is not much, these two specialties do represent more than 50 percent of all acute patients. In conclusion the AAU seems a success in terms of reducing the average LoS of patients, not for all medical specialties, but for a large group of patients.

5.2 Performance analysis AAU: inflow phase

In this section, insight will be given into the inflow phase of patients who are admitted to the AAU. The number of admissions and the day and time at which these admissions take place will be examined. After that the division of the specialty of admitted patients will be discussed. Lastly the access time performance indicators, the AAU access time and ED-AAU access time, are reviewed.

5.2.1 Number of admissions

Number of admissions per month

The number of admissions at the AAU in the first three months are 516, 532 and 525, for respectively September, October and November. These numbers suggest a relative stable inflow of the number of patients per month, but comparing only three values does not say much. To be more certain about the presumed steady inflow of patients, the number admissions per week are considered. The number of admissions per week gives a more genuine view of the variation in the inflow.

Number of admissions per week

The number of admissions per week are displayed in Figure 8, note that all weeks in the analysis period have 7 weekdays. On average 121 admissions are done at the AAU per week. The variation between the weeks is very small; the CV is only 6.8%. Furthermore, the lower inflow in weeks 36 and 42 have their reasons, week 36 is the start week of the AAU when many things were new also for patients, and week 42 is the fall holiday. When taking those reasons into account it is likely that the real average is slightly larger and the CV even smaller. All in all the inflow of patients per week is stable around 121 admissions per week.

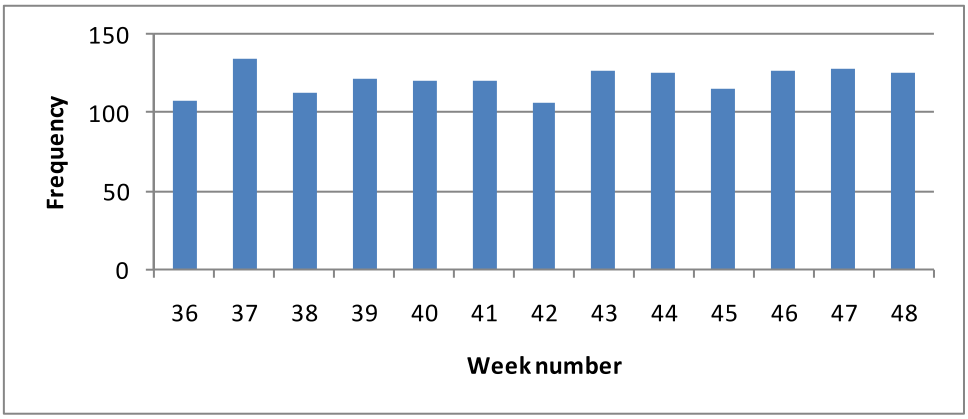

Figure 8: Number of admission per week

Number of admissions per day of the week
The inflow of patients has been reviewed on a month and a week level, but can also be reviewed on a daily level: how many admissions are done on which day of the week. The inflow pattern per day of the week can be found in Figure 9. This figure shows a relatively stable inflow of patients on weekdays and a clearly lower inflow at weekends.
On an arbitrary day, there are 17.29 admissions at the AAU. The day with on average the largest number of admissions is Monday (μ=20.77) and the day with the lowest number of admissions is Saturday (μ=11.85), detailed statistics of all days can be found in the SPSS output in Appendix N. The variation of admissions per day of the week in relation to the average number of admissions, the Coefficient of Variation (CV), is for most days around 24%. On Wednesday, however, the CV is much lower, 15.42%. Although the CV does indicate the extent of the variation, it is also important to look at the range of the number of admissions. The AAU is ought to admit 'all' acute patients, thus it needs to react on the total range of number of admissions. With regard to the number of beds, the minimum number of admissions is not as important as the maximum number of admissions. The maximum number of patients that are admitted to the AAU on a day is 28, this has happened on a Monday, Thursday and Friday. On these top days 87.5% of the AAU beds are needed for new admissions. This means that about 28 patients need to be flowing out of the AAU. These days put tremendous pressure on the AAU and the hospital as a whole. On those days the admitted patients do not have the possibility of staying the full 48 hours and hereby the chance to discharge the patient while admitted to the AAU is reduced. On those days the AAU cannot fulfil its intended function, several patients need to be transferred prematurely. This is no recommendable situation and perhaps solutions have to be found for these days with a high turnover.

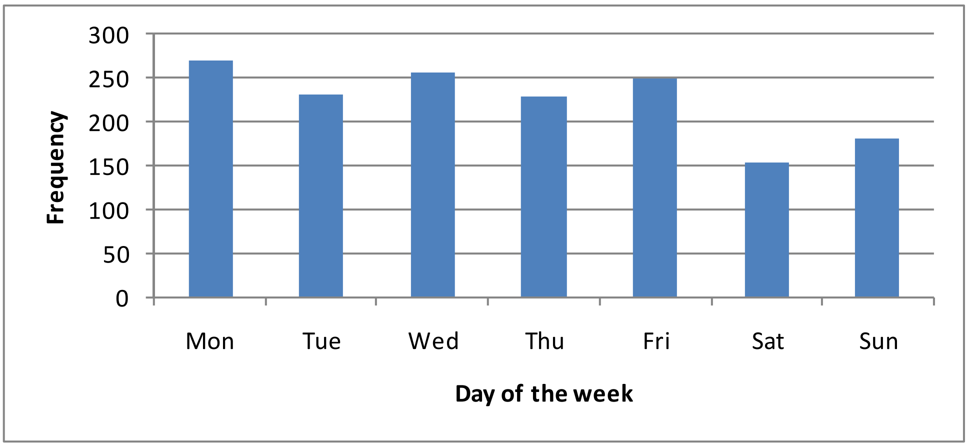

Figure 9: Number of admissions per day of the week

Before any statistical test can be performed to see if the inflow differs between the days, and if the inflow is lower at weekends, the normality of the inflow per day of the week needs to be checked. The normality has been checked in Appendix N, it was found that the number of admissions per day of week is normally distributed. Since the number of admissions per day of the week is assumed to come from a normal distribution, parametric statistical test can be used to compare the means of the number of admissions per day of the week. It can be tested if the number of admissions at weekends differs significantly. The test will only reveal if the number of admissions on a Saturday and Sunday are lower than on a Monday, Tuesday, Wednesday, Thursday and Friday.
One way to test the hypothesis is to compare the 95% confidence intervals of the mean for all samples. When the confidence intervals do not overlap, it can be concluded that with 95% certainty the two samples differ significantly. The 95% confidence intervals for all days of the week can be found in Appendix N. When all confidence intervals are compared it can be concluded that the differences are only significant when weekdays are compared to Saturdays, i.e. at Saturdays the number of admissions are significantly lower than on weekdays. The comparison of Sundays with weekdays, revealed a significant difference for only three weekdays: Monday, Wednesday, and Friday.

Number of admissions per hour of the day

Besides the number of admissions per month, per week and per day of the week, evaluating the number of admissions per hour of the day can also increase the understanding of the inflow of patients at the AAU.
First, the inflow of patients on an arbitrary day is considered. Figure 10 shows the number of admissions per hour of the day. It can be seen that the increase in inflow of patients starts around eleven o'clock and then remains at a high level till eleven o'clock in the evening. From 23:00 till 4:00 the number of admissions stays at a medium level, from 4:00 the number of admissions is at the lowest level till eleven o'clock in the morning. This kind of cycle is present at the AAU about every day. The reason for this cycle is the arrival pattern at the ED. Almost all admitted patients at the AAU (about 90%) come from the ED. Literature (e.g. Lane et al., 2000 or Sinreich & Marmor, 2005), a study performed at the ED of the MMC in VHV a few years ago (Garritsen, 2003) and own analysis, (see the first figure of Appendix O) shows the same pattern of inflow is present at the ED, but shifted a few hours earlier. The pattern shift can be explained by the throughput time at the ED, which will be further investigated in section 5.2, when the ED-AAU access time is considered. From Garritsen (2003) and from consultations of doctors and other staff the late peak in inflow can be explained by patients who have been directed to the ED by their GP. During the morning and around midday GPs see many patients. Some of these patients need acute medical care and are therefore referred to the ED. It then takes some time before the patients really arrive at the ED, because of travelling time, this explains the later peak during the day.

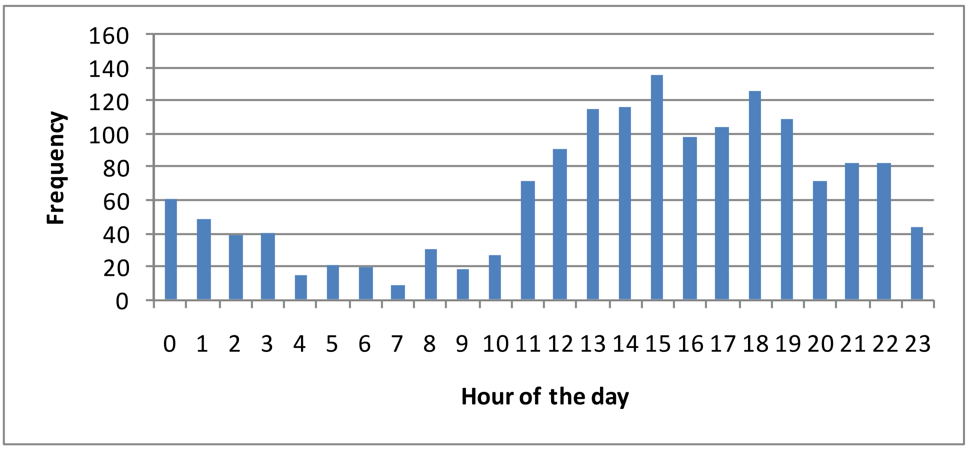

Figure 10: Number of admissions per hour of the day at the AAU

Since there is a difference in the number of admissions at weekends and weekdays it is also constructive to assess the pattern of inflowing admissions per hour of the day for the different weekdays, see the second figure of Appendix O. It appears that the inflow pattern for weekdays is rather similar to the arrival pattern in Figure 10. This suggests that the pattern is also present during weekdays. The patterns per weekday do have much more variation than the summarized daily pattern from Figure 10, this is partly due to the limited number of observations present to create the graph. In total 13 weeks are considered which results in only 13 observations, which is rather small, especially in relation to the arbitrary day which is based on 91 observations. At weekends, however, the pattern deviates, the peaks during the day are much lower, but the inflow during the night and early morning are still level. From this can be concluded that the inflow pattern during weekdays and weekends is different.

5.2.2 Specialty of admission

The division of the medical specialty of admission will be discussed in this section. Just as the number of admissions discussed in the previous section, the specialty of admission is merely to gain insight. The division of the specialty of AAU admitted patients during the inspection period is exhibited in Figure 11. The two main contributing specialties to the AAU are the Internal medicine (INT) and the general surgery (ACH), together they represent over 50% of the patients. The INT and ACH are followed by Pulmology (PUL) and Gastroenterology (MDL), who have a share of 11 and 10 percent respectively. These four specialties together, INT, ACH, PUL and MDL represent more than 75% of the patients admitted to the AAU. When also including the Urology (URO), 7%, Orthopaedic surgery (ORT), 7%, and Neurology (NEU), 5%, more than 95% of the incoming patients are classified. The remaining patients are admitted by other specialties, but do not represent a substantive share to elaborate further on this category.

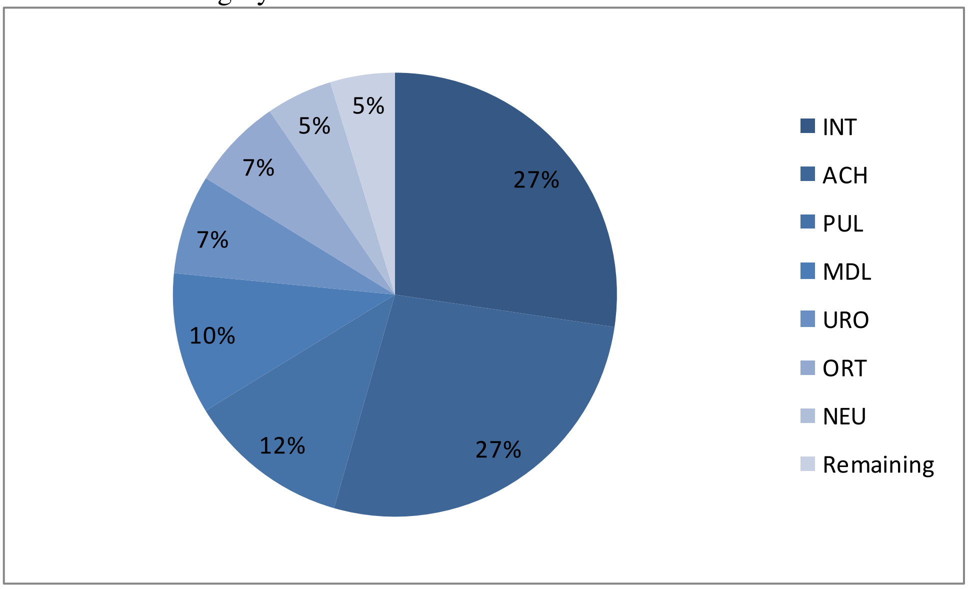

Figure 11: Specialty of admission

It has also been tested if these percentages differ much during the weeks. The results are shown in Table 7. From the coefficient of variation can be concluded that the variation for ACH and INT is relatively small. The variation of ORT and NEU, however, are larger.

Of this analysis, it is important to remember the large number of admitted patients from the specialties ACH and INT, but also the substantive share of MDL and PUL admissions. Later in this report when for instance the time of visiting rounds per specialty is considered, this fact sheds a different light on the figures.

Table 7: Summary statistics of number of admission per week per specialty

Specialty	Count	Average	Standard deviation	Coeff. of variation	Minimum	Maximum	Range
ACH	13	32.77	6.33	19.31%	19	40	21
INT	13	33.08	5.17	15.63%	25	44	19
MDL	13	12.46	3.50	28.11%	6	18	12
NEU	13	5.85	2.58	44.08%	3	11	8
ORT	13	8.08	5.25	65.02%	3	21	18
PUL	13	14.31	4.91	34.29%	6	22	16
URO	13	8.77	2.31	26.40%	4	12	8

5.2.3 Access time

AAU access time

The time performance measures that apply to the inflow phase are discussed in this section. First, the AAU access time, the difference between the AAU notice time and the AAU start time is discussed. After that, the ED-AAU access time is examined to consider how long the patients stay at the ED before the patient is transferred to the AAU.

The AAU access time represents the time it takes from the moment the patient is announced at the AAU, to the moment the patient is in a bed at the AAU. Most of the time the access time will be very small, since most patients come from the ED which is located very close to the AAU. For a small number of patients larger values are expected, because several patients have been admitted after being seen at the outpatient clinic in EHV. These patients will need some time to travel to MMC VHV.

On average it takes 42 minutes from announcement to arrival of patients at the AAU, see Appendix P. The average is quite high, but several outliners have a considerable influence on the mean and need to be removed. Values larger than 0.20833, or 5 hours, were deleted because these values did not represent normal behaviour. The boundary of 5 hours was chosen, because there were only few values larger then 5 hours (16 of the 1573). Access times smaller than 5 hours are larger in number; see the box-plot in Appendix P. When these outliers are removed from the subset the new average access time is slightly reduced to almost 35 minutes, see Appendix P for the summary statistics of the access time without outliers. When also the box-plot without outliers is considered, in the same appendix, one could see that, many access times are quite small.

The analysis of the AAU access time shows partly expected behaviour, some larger values for the access time and many short access times, and partly unexpected behaviour, a rather large average AAU access time of 35 minutes. Further analysis of the ED-AAU access time in combination with the AAU access time will possibly increase insight in this large AAU access time. Now the ED-AAU access time is considered first, before going into the elaborated analysis.

ED-AAU access time

With the creation of the AAU, also changes were made at the ED. One of the changes is that the ED can always let its acute patients flow out, since the AAU guarantees a free bed. This has permitted the ED to create strict throughput norms. The ED has a LoS goal. All patients should have left the ED within three hours after arrival. Since the focus of this report is on the AAU and not on the ED, it is investigated if the new performance targets are met for patients that are admitted to the AAU.

The ED-AAU access time is calculated by AS_j - ES_j. On average the ED-AAU access time is equal to 2.72 hours, which is about 160 minutes, see Appendix Q for the sample statistics. The variation is relative large, since the CV is just over 54%. The histogram in Appendix Q shows the large variation. It is striking to see such a large number of patients still not transferred to the AAU within 3 hours. Only about two thirds of the patients are transferred to the AAU within the target time of 3 hours.

One has to keep in mind that the analysis made here is based on the start time at the ED till the start time at the AAU, which means that these values also include the AAU access time. Strictly speaking this way of analysis is correct, since the real transport time from the ED to the AAU is only a couple

of minutes and has a marginal influence on the AAU access time. Yet, the AAU access time is not negligible, with an average of 35 minutes, and does have a significant contribution to the ED-AAU access time of about 18%. Therefore it is not fair to allocate all the AAU access time to the ED. In reality delays will be present at both the ED and the AAU. A delay can be present at the ED for instance when a patient has been digitally transferred, but before the patient was physically transferred the ED needed to check up on another patient. The delays at the AAU could be present because of administrative errors. For instance the patient is not assigned to a room immediately after the patient is in the assigned room. From own experience, from working with the ED and the AAU, the extra waiting time at the ED is expected to be larger, then the waiting time at the AAU.
It seems that the ED-AAU access time is relatively large; at least many patients stay longer at the ED than the aimed for 3 hours. Perhaps, when the AAU access time is subtracted from the ED-AAU access time, see next section, the results are somewhat improved.

ED-AAU access time minus AAU access time
In Appendix R the statistics and graphs of the ED-AAU access time minus AAU access time are displayed. The mean throughput time is 2.04 hours and the percentage of patients ready at the ED within 3 hours has increased to about 83%. This means that by subtracting the AAU access time from the ED-AAU access time, the average throughput time has decreased by 41 minutes. The percentage of patients discharged has increased by 16%. So the AAU access time has a large impact on the achievement on the time goal at the ED. The real ED-AAU access time will probably lie in between the two extreme interpretations, but, as reasoned before, it will be more closely to the calculated ED-AAU access time then to the ED-AAU access time minus AAU access time.
From all access time analyses it is clear that the norm, patients away at the ED within 3 hours, is often exceeded, especially when the AAU access time is included. Furthermore, the AAU access time is much larger than expected. This raises questions about the strictness of registration, does the digital moment reflect the real moment, which is especially important when a small and sensitive norm is kept. Caution should be kept concerning the interpretation of the data of the ED, especially with regard to the precise throughput time.

5.3 Performance analysis AAU: stay phase

Many activities take place during the stay phase of the patient at the AAU. Most of the activities described in section 2.2.2 are considered here. In this section more insight is obtained in the patients' stay and many activities related to the patients stay. First, the AAU LoS is examined, and the LoS performance measures are evaluated. The bed utilization is considered next. The utilization is not only captured in a graph, but also trends per day of the week and hour of the day are found. Third, the visiting rounds are evaluated i.e. at what times are the visiting rounds done and are these rounds accompanied by consultants.. When all processes at the AAU itself have been discussed, the processes during the stay phase which are done at other departments, like lab and radiology, are discussed last. The performance of these departments, and the relation these departments have with the AAU are considered. The lab, radiology, surgery and function department are discussed successively.

5.3.1 AAU Length of Stay

The AAU LoS is the first property of the AAU stay phase that is presented here. A frequently used measure to evaluate the LoS is the average LoS (Marshall et al., 2005). This simplistic approach does however not take into account the underlying distribution. Therefore, the underlying distribution is also considered, see Figure 12. The summary statistics of the AAU LoS, generated with Statgraphics, can be found in Table 8. The average AAU LoS is larger than 1 day, 28 hours to be precise with a standard deviation of 16.5 hours. The distribution of the AAU LoS, in Figure 12, does indeed explain the properties behind the average LoS.

Table 8: Summary statistics of the AAU LoS

Statistic	Value
Count	1573
Average	1.17
Standard deviation	0.69
Coeff. of variation	58.91%
Minimum	0.00
Maximum	5.03
Range	5.02
Stnd. skewness	14.27
Stnd. kurtosis	9.67

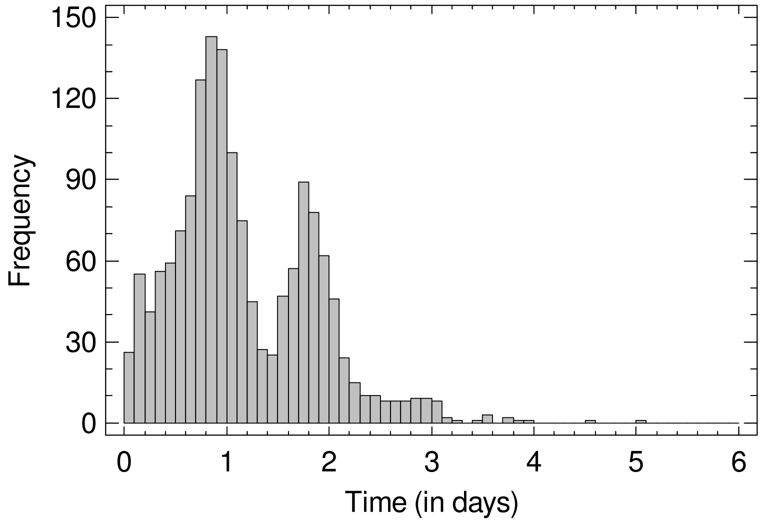

Figure 12: Histogram of the distribution of the AAU LoS

The structure of the LoS distribution, with peaks just before one and just before two days, and with a drop around 1.5 day. These properties can be explained by the inflow and outflow behaviour of the AAU. At the AAU 24 hours a day patients can flow in. By day more patients are admitted then during nights, as can be seen in Figure 10. When also the restriction of outflow at the AAU is taken into consideration, no transfers during the evening and night, the reasons for this specific distribution are explained. It will become even clearer when Figure 13 is considered. This figure shows the LoS for all patients categorized by their hour of admission. So all patients admitted during 13:00-13:59 are displayed above 13. Each dot in this figure represents a unique admission done at a specific hour with the accompanying LoS, during a specific hour. The gaps in the LoS distribution, which are present due to the outflow restriction, are clearly visible. This in combination with the inflow pattern explains the peaks and drop in the AAU LoS distribution.

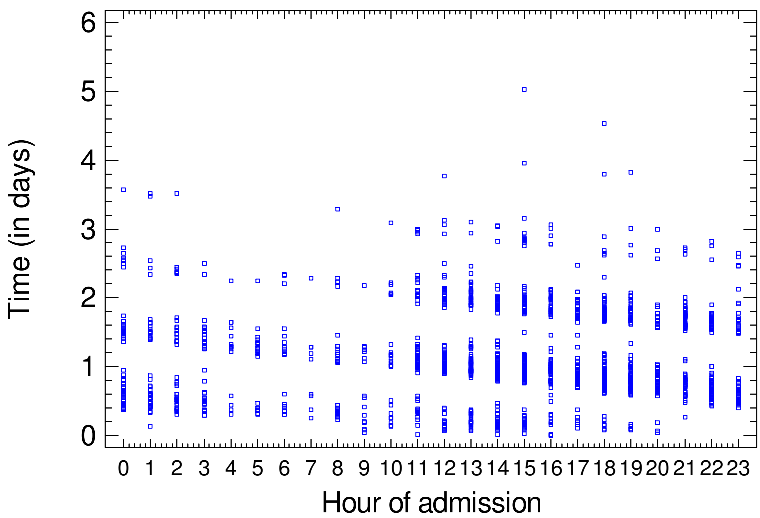

Figure 13: LoS per admission hour

Besides the insight that is gained from looking at AAU LoS, also a performance norm can be evaluated. MMC introduced a norm for the AAU LoS saying that 80% of the patients should be discharged within 48 hours. This percentage was attained in all three months. The discharge percentages are 92, 91 and 85 for respectively September, November and December. These numbers show a negative trend, but since there are only three observations it is much too soon to conclude anything on these numbers. What is clear is that the discharge percentages are well above their intended level.

One number that is somewhat worrying is the maximum LoS. At least one of the patients stayed somewhat more than five days at the AAU, while 48 hours is the target. The distribution luckily shows that the LoS of five days was an incident, since there are only 2 values larger then four days. Only slightly more than 1% of the patients stayed longer than three days, which does not indicate worrying behaviour.
In general the AAU LoS shows good results, the targets set are attained, and only a small number of patients stay longer than 3 days at the AAU.

5.3.2 Bed utilization

One measure which is very closely related to the AAU LoS is the Bed utilization. The Bed utilization will give more insight in the number of patients staying time at the AAU at the same, and the variation of this number. First the performance per month is assessed, after that a more detailed analysis is made, of the utilization per week, day and hour.
Some statistics of, or related to, the bed utilization per month are displayed in Table 9. Keep in mind that in November the number of beds increased from 28 to 32. The statistics in the table show an increasing number of nursing days per month, while the number of admissions per month did not increase much. This resulted in a higher AAU LoS and a higher bed utilization. It seems the pressure on the AAU has increased during these three months; the reasons for this will be further inspected in the remainder of this report. But it is still too early to tell if this is a trend or merely the result of natural variance.

Table 9: Bed utilization figures

Month	Number of admissions	Average AAU LoS (in days)	Sum of nursing days	Average number of beds utilized	Bed utilization
September	516	1.08	541.22	18.04	64%
October	532	1.14	606.59	19.57	70%
November	525	1.28	665.74	22.96	72%

The variation in AAU bed utilization over time can be inspected in Figure 14. Note that the dates displayed on the x-axis correspond to the starting day of a week (Monday. The variation in Bed utilization is rather large: there are moments with a bed utilization equal to 100%, but also moments when the utilization is only 30%. Such a high variation is to be expected, since the AAU has to deal with unplanned, acute admissions.

Bed utilization per day of the week

In section 5.2.1, it was shown that the numbers of admissions differ per day of the week, such a pattern is also expected to be present in the bed utilization. The lows in bed utilization in Figure 14 are mainly at the end of the week and the start of the week. To further investigate the presence of such a pattern, the bed utilization is now analysed per day of the week.

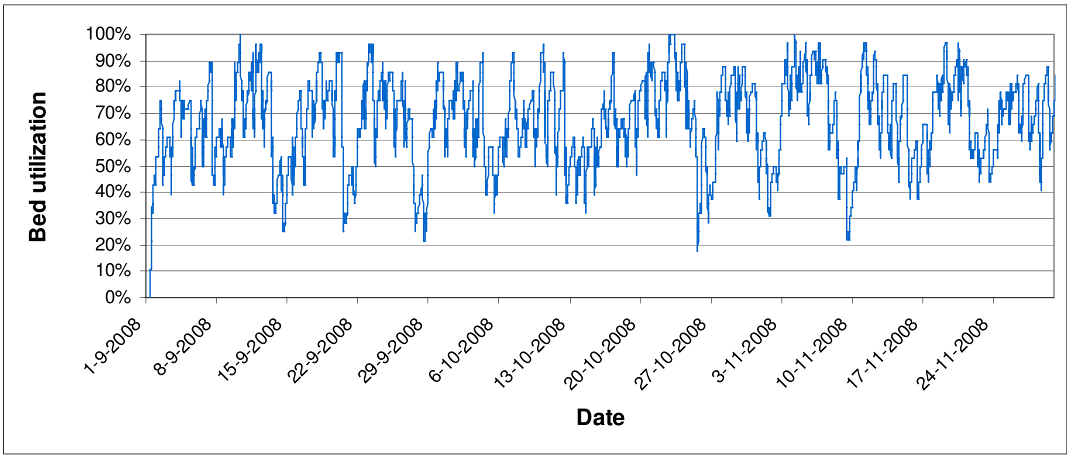

Figure 14: AAU bed utilization

The average bed utilization at weekends is lower than during the week, see Figure 15. The average bed utilization is not only lower on Saturdays and Sundays, but also lower during Mondays, which can be explained by the low utilization level on Sundays and the late peak in number of admitted patients to the AAU during the day. At Mondays many patients are admitted, but are only at the AAU later that day. In general the variation in bed utilization is low, see Appendix S. Only one day of the week, Sunday, has a relatively higher variation.
To see if the utilization during the weekend is really significantly smaller that during weekdays statistical tests must be conducted. The results of the normality test done with SPSS can be found in Appendix S. From the analysis can be concluded that the bed utilization on the AAU per day is not normally distributed for Tuesdays and Wednesday. The data of the other days seems to be normally distributed, since no evidence has been found to undermine this conclusion. To test the difference in utilization, the 95% confidence intervals in the summary statistics of Appendix S can be used for all days, except Tuesday and Wednesday. To compare the utilization levels at weekends with Tuesday and Wednesday levels non-parametric tests are used, just as in section 5.1 when the LoS from before AAU are compared to during AAU. The result of these non-parametric tests can also be found in Appendix S. From the 95% confidence intervals and from the non-parametric tests can be concluded that for all combinations of either Monday, Saturday or Sunday with either Tuesday, Wednesday, Thursday or Friday, the former has a significantly smaller utilization level than the latter, except for the combination Monday-Friday. This means that at weekends and on Mondays fewer patients stay at the AAU then on the other weekdays. This insight could aid in determining nurses staffing levels.

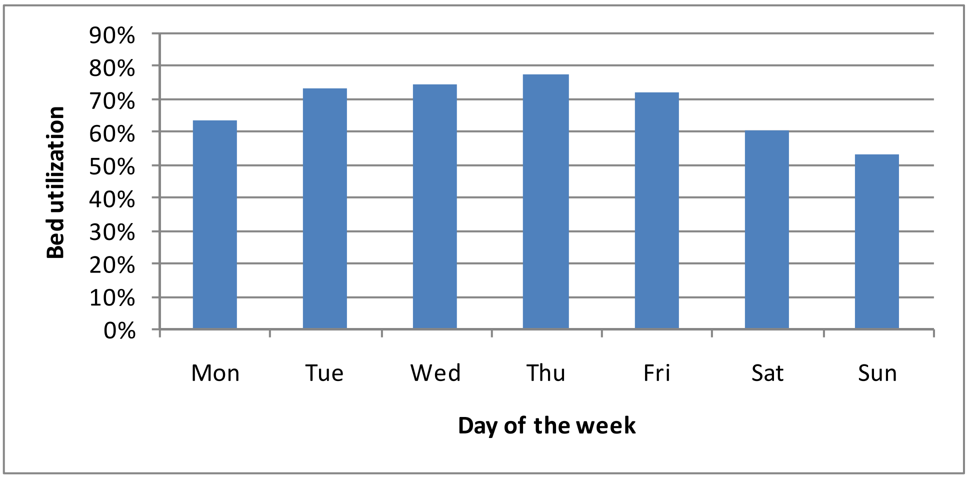

Figure 15: Average bed utilization per day of the week

Bed utilization per hour of the day

To gain even more insight in the utilization patterns of the AAU, the average utilization levels per hour of the day are considered. Since there are statistical differences between the utilization levels per day of the week, it is very likely that utilization pattern per hour of the day is also different per day of the week. Therefore in Appendix T for each day of the week a figure with the average utilization levels per hour of the day is plotted. In Figure 16 one example is given, the average bed utilization per hour of the day of Tuesdays. Although the figures in Appendix T do differ somewhat between the days, a general pattern does exist. Everyday there is a drop in the utilization around 17:00 after that the utilization steadily climbs to its peak around 8:00, after which it starts to drop to the low around 17:00. This specific pattern can be explained by the combination of the in- and outflow pattern per hour of the day; many patients are admitted to the AAU after 17:00, while most patients have already be transferred or discharged around that time. Furthermore the restriction of no transfers during evening and nights makes the bed utilization to climb during nights.
Now the utilization has been analysed from different detail levels, much more insight is gained in the processes at the AAU. Despite the predicted bed problems, the bed utilization has not shown worrying behaviour. There were only few moments when the bed utilization was 100%. However, since the number of admissions seems to be rising, it remains to be seen if the number of beds will be sufficient in the coming months. So the utilization levels should be inspected in the future to see if high

utilization levels, and thus bed problems, do occur. But based on the first three months of data it is clear that the number of beds are sufficient.

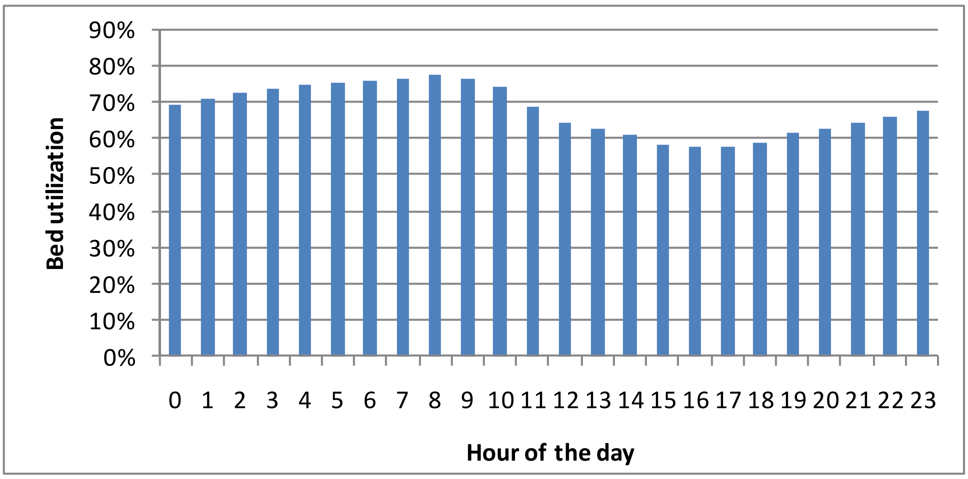

Figure 16: Average bed utilization on Tuesdays per hour of the day

5.3.3 Visiting rounds

At the AAU visiting rounds are done twice a day during weekdays and once a day during weekends. In order for the visiting rounds to be effective, two pre-conditions have to be met. First, as many results as possible should be available from requested tests, and second the consultant must participate in the visiting round. On weekdays the ward rounds take place around 9:00 and around 16:00. These times have been chosen with care, to reckon with different parties. For instance, it allows for additional tests to be performed and reported before the next visiting round. Also enough time should be present to transfer any additional patients before 18:00 to other wards. In this section it is checked if the visiting rounds were done in time and if the visiting round was accompanied by a consultant. Later in this report, when the laboratory and the radiology department are considered, it is checked if the results of the performed tests are known in time i.e. before the start of the visiting round. In this section the weekend visiting rounds will not be considered, since they take place only once a day at a non-commanded times.

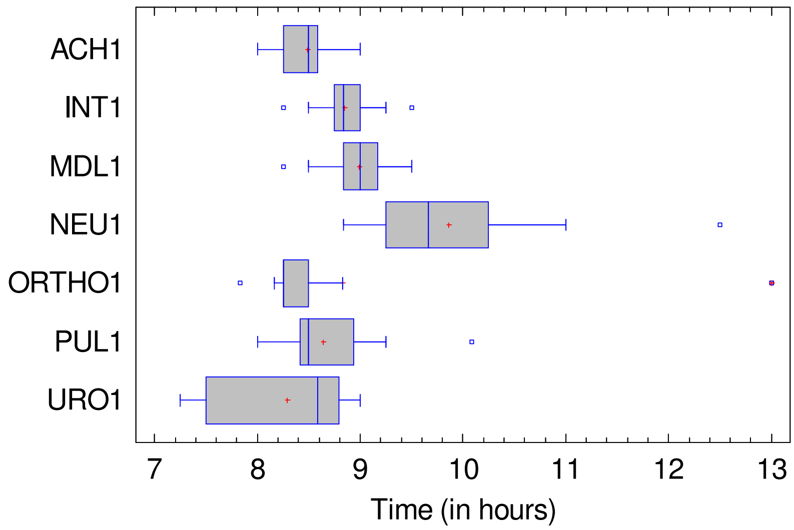

Figure 17: Boxplot of time of morning visiting rounds per medical specialty on weekdays

During November, nurses kept track of the starting time of visiting rounds and if consultants were present during this visiting round. In Figure 17, a box and whisker plot is shown of the morning visiting times per medical specialty. In Figure 18 a similar plot is drawn for the afternoon visiting round. As can be seen, most specialties start their morning visiting round before 9:00. MDL mostly

starts just after 9:00, and NEU nearly always starts after 9:00. Furthermore the variation in starting time is small, most medical specialties started their visiting rounds within the range of one hour. In conclusion, all medical specialties, except for NEU, start their visiting in time and start their visiting rounds persistently before 9:00.
Now the evening visiting rounds are considered, see Figure 18. The intended start time of the visiting round is 16:00. Practically all specialties start there visiting round after 16:00. INT scores best, but even for INT most visiting rounds start after 16:00. Apart from the late starting time, also the variation in starting time is disturbing. Practically all specialties have a range of two hours or more in which they start their visiting round, ACH even has a range of more than 4 hours in which they start their visiting rounds. The high variation in combination with the late start of the visiting rounds makes the afternoon visiting rounds troubling.
These late afternoon visiting rounds affect the effectiveness of the evening visiting rounds in two ways. First, transfers of patients to other wards need to be done before 18:00, when visiting rounds start late there is little time left to arrange a possible transfer. Second, the later a visiting round is done, the smaller the probability that a test can be performed that same day. When the test is requested, the results can only be considered with the next afternoon visiting round, instead of the next (morning) visiting round. This could limit the effectiveness of the next visiting round.

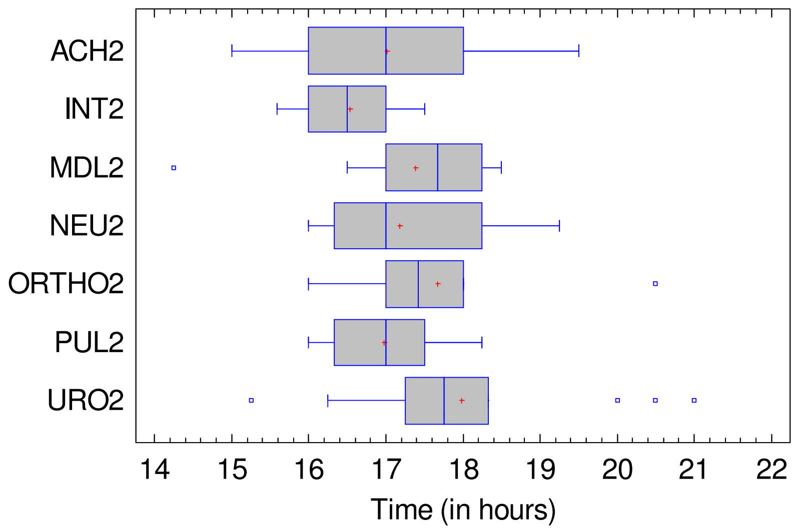

Figure 18: Box plot of time of afternoon visiting rounds on weekdays per medical specialty

Besides the time at which the visiting round was done, also the presence or absence of the consultant was tracked by nurses. The percentage of times a consultant of a specific specialty was present during a visiting round is shown in Table 10. Overall the percentages are quite high around 90%, this means that almost all the time a consultant was present. There are two specialties that show troubling consultant presence: ACH and ORTHO. The low percentage of ACH is mainly due to the absence of consultants during afternoon visiting rounds. The afternoon ACH visiting rounds are in only 15% of the time accompanied by a consultant. The low percentage of OTRHO consultant present is more consistent at both visiting rounds. In 70% and 50% of the times at respectively the morning and evening rounds a consultant is present. Overall the visiting rounds are well attended by consultants, only the afternoon rounds of ACH and both rounds of the ORTHO need improvement to increase the effectiveness of the visiting rounds.

Table 10: Percentage of times a consultant was present at visiting rounds

ACH	INT	MDL	NEU	ORTHO	PUL	URO
63%	88%	91%	96%	57%	91%	97%

5.3.4 Other departments

Just as every ward in a hospital, the AAU is dependent on other departments for diagnostic test, to timely diagnose the patient, and for appropriate treatment. The relation of the AAU with the other departments will be examined in this section. It is investigated how the departments operate and how these departments operate in relation to the AAU. As is clear from research, see e.g. Matta and Patterson (2007), local performance optimization does not always result in the best performance for the system as a whole. Therefore also the global performance, here the department's relation with the AAU, will be examined. The departments that will be examined are: clinical lab, radiology, surgery and function departments. Per department, six different performance measures are used to assess the department's performance, these measures are: queue time, true queue time, service time, wait time, throughput time and tardiness. First the performance of the clinical lab will be assessed, after that the function departments, surgery and radiology will be discussed.

Clinical lab

The clinical lab mainly performs blood analysis, but e.g. urine analyses are also done at the lab. Blood samples are taken by lab personnel four times a day with lab rounds, at 8:00, 11:00, 14:30 and 20:00, or if rush is needed someone will come immediately to draw blood, a so called CITO test. Remember that only tests with a throughput norm are used in the analysis. Of the six performance measures that can be applied to the lab, only three will be used here: throughput time, service time and tardiness. The queue time isn't used since no notice time is available for the lab, the precise moment of request isn't recorded. The true queue time isn't used, because the start time does not represent the real start time, but the time the sample has been brought to the lab. Wait time doesn't apply to the lab since most results are immediately entered in the databases when known. So an extra authorization step isn't needed for the lab. First the throughput time will be assessed, after that the service time, and finally the tardiness is considered.

The throughput time is normally calculated by $TR_{i,j,k}$ - $TN_{i,j}$. However with the lab there is no result time, so the end time will be used. This means that here the throughput time is calculated by $TE_{i,j,k}$ - $TN_{i,j}$ Furthermore, keep in mind that the notice time of the lab is not the real notice time. It depends on the type of test if the notice time is used or not. When test are done for a specific lab round the notice time will be the time of the specific lab round. Is the test not part of a lab round, then the notice time will in most cases be equal to the start time, the time the sample is at the lab.

The throughput and service time is analysed per type of test, CITO, urgent and normal, since different norms are set for these types of tests. First, the CITO tests are considered. CITO tests require immediately attention of the lab, because most results must be available within 45 minutes. The throughput time of CITO tests is on average 0.63 hours (38 minutes). This seems rather large, but as can be seen in Table 12, the maximum throughput time is more than 3.5 hours. This value has a large impact on the sample mean. The service time statistics show an average of 0.50 hours (30 minutes).

Now the CITO norm is discussed. Of all these CITO tests it has been checked if they passed the norm, taking into account a different norm of 120 minutes for some CITO tests. Table 11 shows the fraction of tests that were done within the norm time. Note that the norm is set for the service time only, but since the throughput time has more meaning at the AAU, especially for lab rounds, this fraction is also shown. Of all CITO tests, 91% were ready within the norm set. Although this fraction is slightly lower than the projected 0.95, further analysis is needed to see why certain test took much time.

Table 11: Fraction of lab test ready within the norm

Time measure	CITO (mostly 45 min)	Urgent (120min)	Normal (360min)
Service time	0.91	0.98	0.99
Throughput time	0.80	0.93	0.99

Now the Urgent tests are considered, the service time of these tests should be smaller than 120 minutes. The sample statistics of both the throughput time and service time are stated below in Table 12.. What immediately stands out, are the large differences between the throughput and service time.

The service time is only 0.54 hours, while the throughput time is with 1.19 hours more than twice as large. The reason for this large difference is not clear; apparently it takes a lot of time from the moment of request until the sample is at the lab. However when the fraction of tests ready within 120 minutes are compared the difference between the throughput and service time are not large. The service times score only 5% higher. This indicates that still most results are known in time. The fraction of completed tests in time for the service time is at a high level of 0.98. So the internal processes at the lab run smoothly. However it could be insightful to further analyse the reasons for the relatively longer throughput time, since more than 50% of the time is spent on getting the sample, which has a negative impact on the fraction of tests completed.
Finally the normal tests are inspected, for these tests also the throughput time and service time statistics are shown in tables. As with the urgent tests, the difference between the throughput time and service time is quite large, although the difference is smaller. Apart from the large difference between the throughput and service time, no further improvements are needed. Especially since more than 99% of the tests are done within the 360 minutes norm time.

Table 12: Sample statistics for all type of lab tests

Type of test	Type of time	Count	Average	Standard deviation	Coeff. of variation	Minimum	Maximum	Range
CITO	throughput	288	0.63	0.55	86.30%	0.07	3.53	3.47
	service	288	0.50	0.42	84.93%	0.05	3.52	3.47
Urgent	throughput	4756	1.20	1.44	120.52%	0.05	30.52	30.47
	service	4756	0.54	0.45	83.55%	0.05	10.35	10.30
Normal	throughput	4299	1.25	1.25	100.41%	0.05	32.87	32.82
	service	4299	0.71	0.82	115.99%	0.05	14.10	14.05

Now the throughput time and service time have been assessed, the tardiness of the lab is inspected. The tardiness indicates the time the result of a lab test was too late in relation to the ward round. For the analysis here it is important at what time during the day the results of the tests are available. Therefore the division of lab test in CITO, urgent and normal does not make sense here. It is better to use the division of the lab rounds instead. Remember that lab tests are done at a specific time during the day, at 8:00, 11:00, 14:30 and 20:00.
From the analysis of the visiting rounds, see section 5.3.3, it is known that visiting rounds are done around 9:00 and around 17:00. Since the average throughput time of normal lab tests is 1.25 hours, only two lab rounds are useful to investigate further. All tests of lab rounds done at 11:00 and 20:00 have several hours to complete before a new ward round is done. Therefore these lab rounds aren't included in the analysis here. Apart from these two lab rounds also the lab round of 14:30 is omitted from this analysis. Analysis shows that the throughput time for these lab round tests is on average 1.20 hours and a CV of only 40%. This means that almost all tests of the 14:30 lab round are finished before 17:00. So the tardiness will be very low. Note that when visiting rounds would start at the prescribed time of 16:00, still most results of the 14:30 lab round would be available. The lab round of 9:00 is investigated more thoroughly, since the time of lab round is only one hour prior to the morning ward round. This lab round is also most frequently used by doctors; about 88% of all lab round tests are done at 9:00.
The tardiness analysis done here will not focus on the precise tardiness of all performed tests. Since it is very time consuming to match every single lab result to the right ward round of a specific specialty at the precise day, and since only ward round data is available for the month November, a general analysis is performed. For the tardiness analysis here, the cumulative fraction of performed lab tests finished at a specific time of the day is compared to the start time of all lab rounds. The analysis is shown in Figure 19. This figure clearly shows that most lab rounds have already started when a limited amount of lab results are known. For example at 8:30, 40% of the visiting rounds have started while less then 10% of lab results are known, and at 9:00 when 80% of the visiting rounds have

started only 40% of lab results are known. It is very likely that at the start of a hospital round the latest lab results of the patient are not available.
The precise effect of a too late laboratory has not been tested. The effect will be different for different patients, depending on their medical well-being and the LoS at the AAU. If lab results are in time, possibly extra diagnostic tests could have been requested earlier, which would have resulted in earlier results. Furthermore, in-time lab results could shorten patients' LoS directly, when a patient can be discharged dependent on the patients' lab results. As stated the precise impact of too late lab results isn't known, however it is known, from conversations with doctors, that lab results do play an important role in determining the treatment plan. So improvements are desirable.
All in all, the performance of the lab is good; most of the tests are finished within the time norm set. The CITO tests however, do need some improvement to satisfy the service time norm set. Although the lab in itself performs well, the linkage with the AAU is poor. The lab round of 8:00 and the AAU visiting round of 9:00 do not link well. Most of the time lab results are known after the visiting round has already been started. Improvements are needed here.

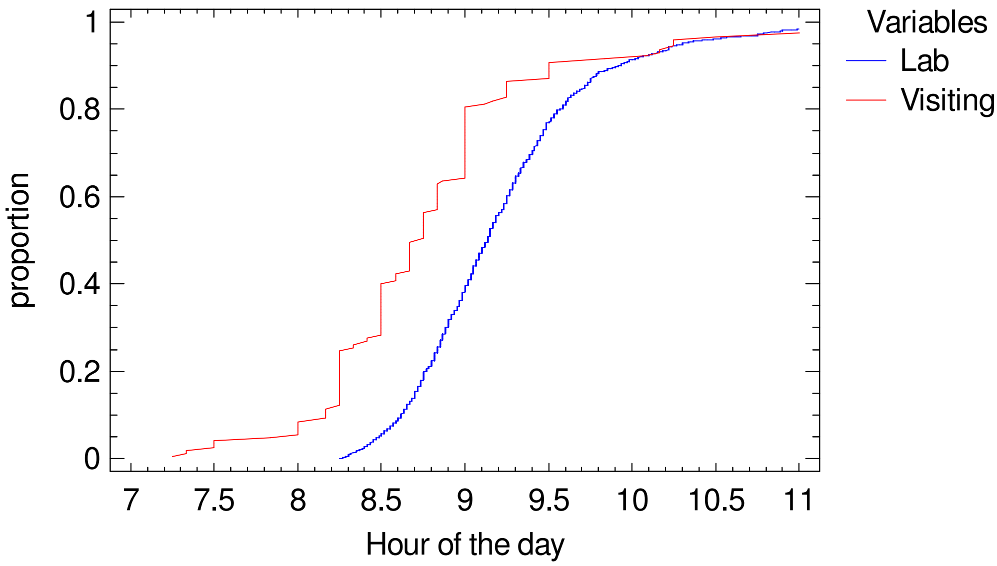

Figure 19: Comparison of lab results known and visiting times in the morning

Surgery
The surgery department is not analysed at the same detail level as the lab and radiology department. This is because of two reasons, first not all data needed is available. Second, and more important, the different performed surgeries are more difficult to compare than radiology and lab tests. This limits the usefulness of assessing the service time.
The only analysis done for surgical patients is determining the impact a surgery has on the AAU LoS. It is analysed if the AAU LoS of patients who have had surgery, is different from patients who did not have surgery. It is expected that the AAU LoS of surgical patients will be shorter than that of other patients, since most patients cannot leave the hospital very soon (within 48 hours) after surgery and need to be admitted to other wards at the AAU. And since the AAU LoS of transferred patients is shorter then that of AAU discharged patients it is expected that this also applies to surgical patients.
The AAU LoS is non-normal distributed therefore the Mann-Whitney U test is used to compare the LoS of both groups. The SPSS output can be found in Appendix Y. The output shows no significant difference between the subset with and without surgery. What is even more striking is that the AAU LoS of patients who had surgery is on average longer than for patients without surgery. So the expected behaviour was certainly not present.
The analysis made has not resulted in the expected clarification. The influence of surgeries on the AAU is still unclear; there is no significant difference in AAU LoS of patients with or without surgery. When more insight wants to be gained, it could be helpful to register the precise moment the surgery was requested: TN_j. Then the throughput time and the queue time would be available for analysis, which will lead to further insight.

Radiology
The second 'other department' that is analysed here is the radiology department. A more detailed analysis of the radiology department can be found in Appendix U. From section 4.5 it is known that only $TN_{i,j,k}$, $TE_{i,j,k}$, and $TR_{i,j,k}$ are used to analyze the time performance of the radiology, all other captured time moments appeared to be invalid. Therefore only three time performance measures can be used: the throughput time, wait time and tardiness. Furthermore the performance measurers will only be applied to normal tests, which are expected to have a throughput time shorter than 24 hours. Now the performance measures are assessed with first the throughput time, after that the wait time and finally the tardiness is discussed.
On average, radiology tests have a throughput time of almost 13 hours, with a high standard deviation of 16.7 hours. When the throughput time is considered per type of test, it is clear that Ultra-sounds have the smallest throughput time, then CT and X-ray. MRI has the longest throughput time. Table 13 shows the fraction of radiology tests ready within 24 hours. In total 84% of the tests are ready within 24 hours. This score leaves some room for improvement; improvement is especially needed for the X-ray tests. The fraction of MRI tests done in time is also quite low, but because many patients need preparation time for an MRI test, the result is less worrying than the performance of the X-ray tests.

Table 13: Fraction of radiology test ready within 24 hours

	X-ray	CT	Ultra-sound	MRI	Total
Service time	0.81	0.88	0.89	0.75	0.84

One of the reasons for the low fraction of tests completed within 24 is the relative long wait time. On average it takes 6.44 hours from the moment the test has been done, until the report is finished. This is quite long. The wait time is also considered in relation to the total throughput time of radiology tests to see what fraction of the throughput time is used by the wait time. On average 36% of the total throughput time is spent on reporting the test. This shows that the there is room for improvement for the throughput time of radiology tests by reducing the wait time.
Now the tardiness is considered. The ideal link of the radiology department with the AAU would be that the requested tests are finished before the next visiting round is done. Then immediately at the next visiting round the results of the tests can be assessed. Keep however in mind, that this ideal behaviour is not possible for all types of tests, several tests need preparation time, but it good to strive for such behaviour. When the ideal behaviour is assessed, logically more tests are finished too late. Especially tests that are requested later in the day, after 15:00, aren't finished before the visiting round the next morning.
So improvements are needed, which could have LoS reductions as a result. When results are timely available the treatment plan can be adjusted sooner. Nevertheless, a better and more detailed assessment of the throughput time is needed to take all relevant aspects into consideration; only then a complete and reliable performance analysis can be made of the radiology department.

Function
The performance analysis of the function department will be just as limited as the surgery analysis, since no detailed time data for function tests is available. As with the surgical analysis here it is also analysed if the AAU LoS is influenced by the presence of function tests. The non parametric tests are done with SPSS and the output can be found in Appendix Z. The output shows the AAU LoS of patients who had a function test is statistically larger than for patients who did not have a function test. Both tests, Mann-Whitney and Kolmogorov-Smirnov Test, are significant at the 0.01 level.
The implication of this result is not clear. Since no further data is available it is not possible to find the reasons behind this longer stay. The most important relation is not clear: is it the function tests which causes the longer AAU LoS, or are patients who need function tests, more likely to recover within 48 hours and stay therefore longer at the AAU. As long as the cause and effect relation regarding AAU LoS and having a function test or not is not clear, no reason for the longer throughput time of AAU patients who had a function test can be given.

5.4 Performance analysis AAU: outflow phase

When the stay phase of the patients has ended, patients will leave the AAU. Some patients will be discharged, others will be transferred to other wards within the MMC. From the inflow analysis it is known that there are differences in the number of admissions per day of the week and there exists a pattern of admissions per hour of the day. Furthermore, it has been shown that the patients' LoS is partly dependent on the hour of admission. These findings will to a large extent be visible when the outflow phase is considered, since the moment of admission plus LoS will result in a moment of outflow. Strictly speaking, the LoS is the result of the admission time and the discharge moment, but since the LoS has already been discussed some behaviour can already be predicted.
This section will give more insight in the outflow phase at the AAU: on what day and hour are the patients flowing out, are they discharged or transferred, if they are transferred, to which ward are they transferred and how much time takes the outflow of patients? Answering these questions will gain more insight in the performance but more importantly the characteristics of the AAU. Taking a warm-up period into account, since no or few patients flow out at the opening, only the outflow of patients during weeks 37 till 48 is used to analyse the outflow characteristics on the AAU.

5.4.1 Number of outflows

Outflow per week

The number of out flowing patients per week at the AAU is visualized in Figure 20. On average 123 patients flow out of the AAU. This number is slightly larger then the average inflow, which is strange, but since the first week of data isn't used here this difference can be explained. The variation in outflow is slightly higher than the inflow variation; the outflow coefficient of variation is almost 10%. The range of possible values is also larger, with a low of 100 and a peak of 140. The reason for this higher variation isn't clear, the variation of the processes at the AAU, will probably account for the larger variation. All in all, the outflow of patients at the AAU is relatively stable around 123 per week.

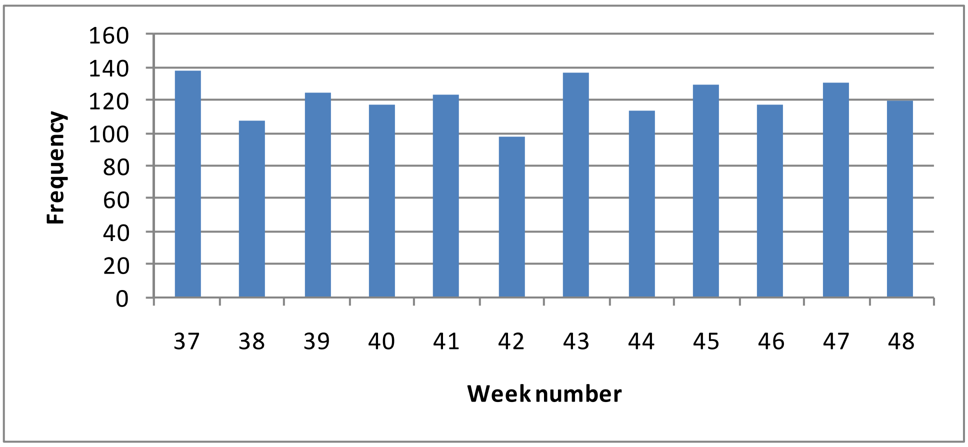

Figure 20: Number of outflows per week

Outflow per day of the week

The second detail level concerning the outflow at the AAU, is the number of outflowing patients per day of the week, see Figure 21. In this figure a peak can be identified in the number of outflowing patients on Friday, and some lower outflows on Sunday. The outflow on Monday also seems somewhat lower, although the difference with other weekdays is smaller. On an arbitrary day on average 17.34 outflows are done at the AAU. On the outflow peak day, Friday, on average 21.92 patients flow out of the AAU, on Sunday, the lower outflow day is 12.25, more statistics can be found in the SPSS output in Appendix V. The coefficient of variation of the outflow is for most days around 23%, only the Friday has a relative lower variation with a CV of smaller than 17%. The range of the outflow lies between 8 on a Sunday and 29 on a Friday.
Now it is tested if the outflow on Fridays is statistically larger than on other days of the week, and if the outflow on Sundays is smaller than on other days of the week. Before this can be tested, normality tests need to be done. Just as before the normality will be tested with three different approaches: the

skewness and kurtosis tests, the normality plots and with two statistical normality tests, Kolmogorov-Smirnov and Shapiro-Wilk. The SPSS output of all these test can be found in Appendix V. All three test methods indicate that only the number of outflows on Sundays is not normally distributed. The non-normality of the number of outflows on Sunday can be explained by one outlier. On one Sunday the number of outflows equalled 24, which is much larger than the single largest value of 15, and this outlier caused the outflow on Sunday to be non-normal distributed. Since this large value is clearly an outlier is has been removed from the set, to be able to use normality based tests to check if there are statistical differences between the number of outflows on Sundays and other days of the week. The new values for the outflows on Sunday can be also be found in Appendix V, they are shown at the end of that appendix.

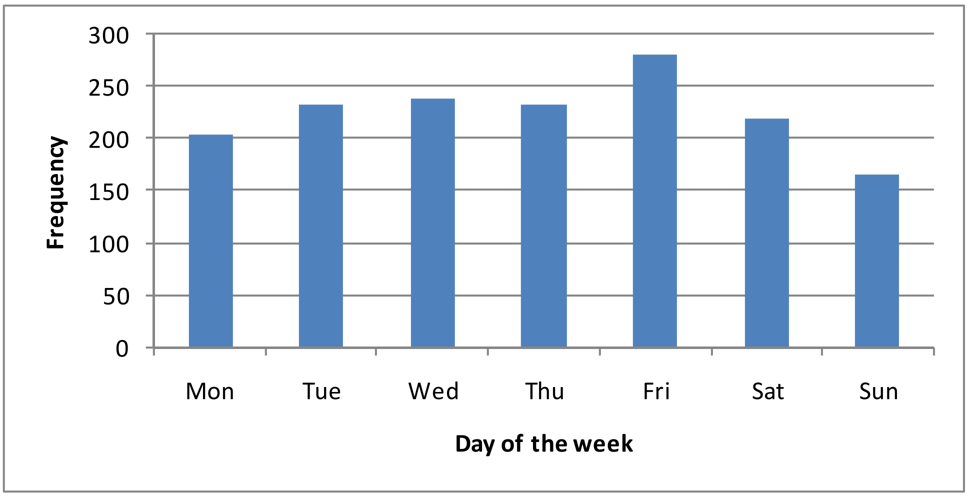

Figure 21: Number of outflows per day of the week

Both predictions, less outflows on Sundays, and more outflows on Firdays is tested with the use of the 95% confidence intervals. All confidence intervals are stated in Appendix V, remember the right values for Sundays are stated at the end of the appendix. The confidence intervals confirm that there are statistically fewer outflows on Sunday than on any other day of the week. The 95% confindence intervals furthermore show that only in comparison to Mondays and Sundays, more patients flow out on Fridays, all other combinations aren't statistically different. Thus on Fridays in general no more outflows are done than on other days.

Outflow per hour of the day

Now the daily outflow pattern has been inspected, the hourly outflow pattern will be considered here. The outflow per hour of the day has been visualized in Figure 22. In the figure a distinction is made between the patients who were discharged and those who were transferred. As can be seen in the figure these two groups of patients have a different outflow pattern. Discharged patients often leave the AAU just after the morning visiting round, around 10:00. A vast amount of transferred patients alos leave around 11:00, but even a larger part of the transferred patients leave after 14:00. The low number of transfers between 12:00 and 14:00, can be explained by the luch break of nurses at regular wards.

Apart from the peaks, the long tail in the number of outflows is also striking, especially for the transferred patients. This is worrying since the receiving wards are not equipped to deal with evening transfers. The AAU was designed to, and with that also the availability of nurses at regular wards, not to transfer any patients after 18:00. As follows from Figure 22, still a large amount of patients is transferred after 18:00, about 18% of tranferred patients leave the AAU after 18:00.

The outflow during nights also need some clarification. These outflows are caused by transfers to specialized wards, by patients who deceased during the night or by administrative errors, so no regular transfers or discharges took place during nights.

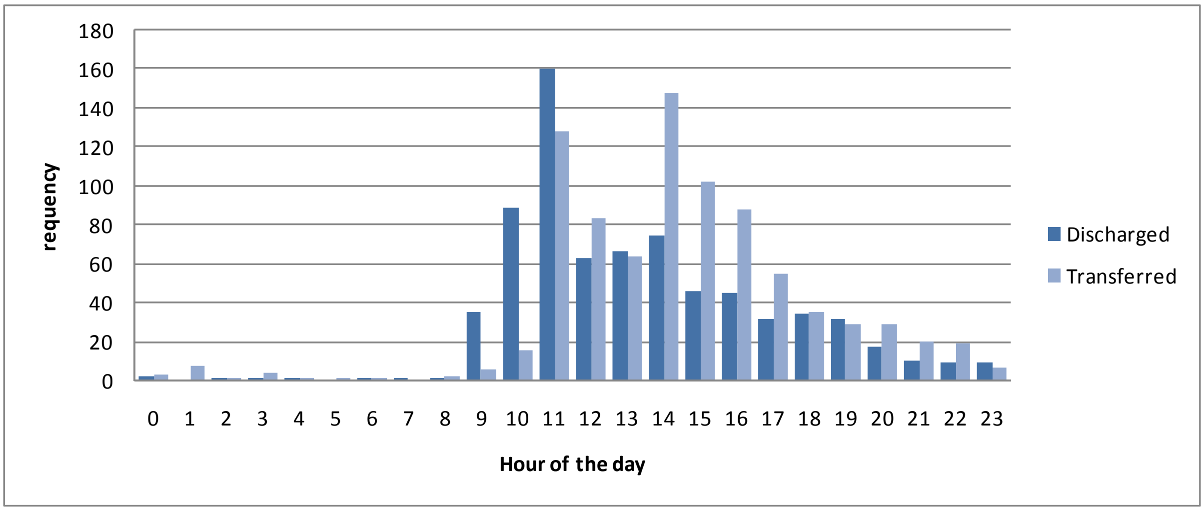

Figure 22: Number of outflows per destination per hour of the day

The analysis of the number of outflowing patients per week, day and hour have resulted in the following insight. The weekly outflow has a larger variation then the weekly inflow, the processes at the AAU cause this variation. The daily outflow analysis has shown that on Sundays less patients flow out of the AAU. Finally, the hourly outflow analysis has shown that the distributions of discharged and transferred patients differs greatly. Furthermore it was found that many transfers are done after 18:00. This is worrying since the design of the AAU did not allow for these transfers. Outflow destination

5.4.2 Outflow analysis per destination

In previous sections the outflow was analysed without considering the destination, except for the outflow per hour of the day. In this section the discharge fraction per specialty is discussed, after that the destination of transferred patients is analysed.
A more detailed analysis of the outflow analysis per destination can be found in Appendix W.

In general the discharge fraction of discharged patients at the AAU is higher than the norm: 46% of the patients were discharged versus 40% projected. When the specialties are considered separately, it is found that almost all specialties conform to the projected discharge percentages set in Appendix E. Only ORT discharged relatively fewer patients within 48 hours at the AAU as projected.
When the specific destination of the patients is considered, i.e. are the patients transferred to their principal ward, it is found that about 85% of the patients are transferred to principal wards.
The detailed AAU data, concerning the time of outflow decisions and tardiness of transferring patients, is inspected next.

5.4.3 Time of flowing out

At the end of the patients' stay at the AAU a decision is made where the patient should go. Is it safe for the patient to be discharged and leave the hospital, or does the patient need to be transferred to another ward at the MMC and receive further care. In case of a discharge, the patient can leave the hospital relatively fast, sometimes transportation and/or home care needs to be arranged, but often the patient can leave the hospital instantly. If a patient needs to be transferred, more arrangements need to be made: a bed needs to be arranged at an appropriate ward, and an appointment needs to be made with the receiving ward regarding the time of transfer. During these actions the patient is still admitted to the AAU and is waiting for its transfer. Although this extra waiting time is needed to make all transfers from the AAU predictable, it is investigated if this time is not needlessly long.
In this paragraph the moment of transfer decision AD_j, the moment of known transfer location AR_j and the moment of planned transfer AP_j are analysed. During November these time moments were registered by AAU nurses. Since data recording by hand has its limitations, the quality of the data is also assessed. After the assessment of the different time moments separately, the performance

measures linked to these time moments will be considered. These are: Queue time and true queue time. In Appendix X a more extensive discussion of the detailed AAU data is given.

AD_j

The first time moment which is assessed is the decision time of end of stay at the AAU; the time at which the doctors decide the patient can be discharged or transferred. As discussed, AD_j is captured by nurses on paper and later entered in the computer. Therefore, the quality of the data is assessed, first. After that, the time moment is analyzed.

The quality assessment of the AD_j data shows many missing observations. The AD_j was captured for only 30% of the patients. One other quality criteria is the generalization of the data. It was also checked and showed that especially data in the last week of November is missing. This means that care should be taken about the generability of the data.

The analysis of the time moment itself showed that most discharge decisions are taken in the morning around the visiting round. With the evening visiting round only a limited number of outflow decisions are taken. This can, at least partly, be explained by the inflow pattern and utilization levels at the AAU. At 16:00, when the evening visiting rounds start, the AAU is utilized poorly. Since many patients have already left the AAU, and the largest part of inflowing patients are yet to come. Around 16:00 there simply aren't many patients for whom an outflow decision can be taken.

Still the result of the analysis are worrying, although less end of stay decisions are to be expected with the evening visiting round, the amount is very low. This suggests that those visiting round are less effective.

AR_j and AP_j

When the end of stay decision has been taken, the patient has to wait till the patient really leaves the AAU or is transferred to other wards. The AR_j time, the moment when the ward of transfer is known, and the AP time, the planned time of transfer, only applies to patients who are transferred to regular wards of MMC. Not all patients, of whom detailed data is available, were transferred to other wards. This has resulted in even fewer available data of the AR_j and AP_j than for the AD_j time moments. All other limitations that were discovered with the AD_j analysis, think of the issue of generability, also apply to the AR_j and AP_j data.

A validity analysis was also performed for the AR_j and AP_j data. The analysis showed that the AR_j and AP_j lack the validity to be used in this report. The main reason for this is the often wrong interpretation of the time moments; see Appendix X for the reasons behind this.

Performance Measures related to detailed AAU data

The detailed AAU data is used to determine the flow out time, queue time and true queue time. Yet, in the previous paragraph it was found that AR_j, and AP_j lack generability and validity and were therefore excluded from analysis. This means that only one of the three time performance measures is used here: the flow out time AE_j - AD_j. This measure reflects on the time it takes, from the moment the doctor decides the patients' stay at the AAU can end, till the time the patients is digitally transferred or discharged from the AAU.

First the general behaviour of the flow out time is assessed. The analysis shows that the flow out time is for 20% of the registered patients longer than 20 hours. This means that the patient discharge decision was taken on day one, but the real outflow took place on day two. This can either mean that no bed was available at an appropriate ward, or the discharge of the patient was postponed. An analysis of the separate groups will increase understanding. The analysis of flow out time per destination shows some unexpected behaviour. The group of discharged patients has on average a longer flow out time. This is strange since it was expected that discharge patients could leave the AAU relatively quick. The higher average flow out time for discharged patients is caused by several larger values that influenced the mean. However, most discharged patients do not have to wait more than 1 day before they can be discharged.

There remains only one analysis regarding the flow out time. Although no reasons have been identified that lead to longer flow out times, and thus no recommendations can be made to possibly reduce the flow out time, it is still captivating to see what fraction of the patients LoS is used by the flow out time. On average 25% of the patients AAU LoS is taken up by outflow time. It was also inspected if there is a relation between the AAU LoS and the flow out time. There seems to be a positive correlation between the two, though there are too many deviant observations for this relation to be statistically significant.

5.5 Performance analysis after AAU stay

For the AAU to fulfil its function it is of grave importance that patients can stay at the AAU up to 48 hours if needed. Not all patients need to stay that long, some are discharged sooner, or have already been transferred to regular wards when it was obvious they have to stay in the hospital longer than 48 hours. However, nurses indicated that several patients were transferred for logistical reasons only, e.g. not taking into account the projected LoS. This behaviour undermines the existence of the AAU. It is clear that patients need to be transferred to other wards when a limited number of beds are available, but then the transferred patients need to be patients who are expected to have a long hospital LoS. In this section it is checked, by inspecting the hospital LoS of patients who were transferred from the AAU to the hospital, if, in retrospect, the right patients have been transferred. In other words, it is checked if the hospital LoS from AAU admission of transferred AAU patients exceeds 48 hours.
The LoS is here calculated by the hospital LoS from AAU admission: HE_j-AS_j. In total, about 4.5% (38 patients) of transferred AAU patients have a LoS shorter than 52 hours (2.167 days). This is somewhat longer norm of 52 hours is chosen since, some longer stay at the AAU is acceptable, and this number fits the data better. The gap, in Figure 23, now serves as the split point. Relatively, 4.5%, is not much, but the absolute number of 38 patients that were transferred to other wards while their hospital LoS from AAU is shorter than 52 hours, is a significant amount. Although the reasons for the transfers are not known, and there is no certainty that the transfer of another patient instead would have decreased this number, the number of 38 is too large. It would be beneficial to both the patient and the wards if only the right patients are transferred, hereby time consuming and invasive transfers can be prevented.

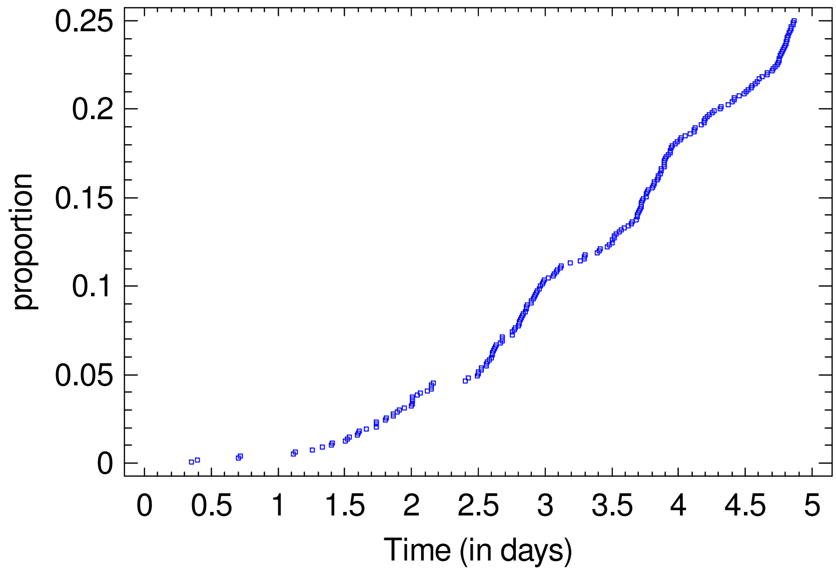

Figure 23: Quantile plot of hospital LoS from AAU

Table 14: Sample statistics of hospital LoS from AAU

Statistic	Value
Count	846
Average	11.29
Standard deviation	11.35
Coeff. of variation	100.49%
Minimum	0.35
Maximum	94.15
Range	93.80
Stnd. skewness	34.48
Stnd. kurtosis	65.90

5.6 Conclusion

In this chapter many performance analyses have been done. These analyses increased insight in the processes at and in relation to the AAU. The fifth research question, what is the current performance of the AAU on the chosen performance measures, has been answered. The analyses showed that the AAU is working well; most expected improvements were gained with the introduction of the AAU. The analyses also showed that there is still room for improvement for several aspects of the AAU. In the next chapter of this report a few of these problem areas will be further analysed and designs will be suggested to improve the performance. Designs will be made for only a few problem areas, due to time, feasibility and other restrictions not all problem areas could be discussed. But first a summary of the results found will be given and more understanding will be given about the performance areas the

AAU can and needs to improve. By discussing this, research question six will be addressed: *What performance areas of the AAU can, and are necessary to improve?*.
This chapter followed the classification of the inflow, stay and outflow phase. The processes were discussed per phase, and assessed by the performance measures introduced in section 3.3. First, the most important insights obtained in the performance analysis are summarized here per phase.
Inflow:

- The inflow of number of patients per week is steady.
- The inflow of number of patients is lower at weekends than on weekdays.
- The inflow of number of patients per hour of the day has a specific pattern, but is not consistent over all weekdays.

Stay:

- Both ACH and INT see around 27% of the patients, PUL and MDL both somewhat over 10%.
- The specific AAU LoS distribution is due to the patients' hour of admission.
- The bed utilization is lower on Saturday, Sunday and Monday than on other days of the week.
- The bed utilization per hour of the day has a specific pattern.

Outflow:

- Most discharge decisions are taken at the morning visiting round.

Now the good and bad performance areas are discussed. In Figure 24 and Figure 25 the different stay phases plus some of the different time performance measures are given. In these figures it is indicated if the performance is particularly good, indicated by green, or particularly bad, indicated by red. First the good i.e. green performance is discussed.
The first performance achievement is not captured in either of the two figures. The good performance is the reduction in hospital LoS of acute patients after the AAU opened in September, The second green performance is indicated in Figure 25, by a green AAU LoS. Almost all medical specialties conform to the objectives set of percentage of patients discharged within 48 hours. The morning visiting rounds are also performed well, the rounds are started in time and most of the time before 9:00. The last green performance is the performance at the Lab. Almost all results of lab tests are known within the set performance levels. Now the bad performance will be discussed.

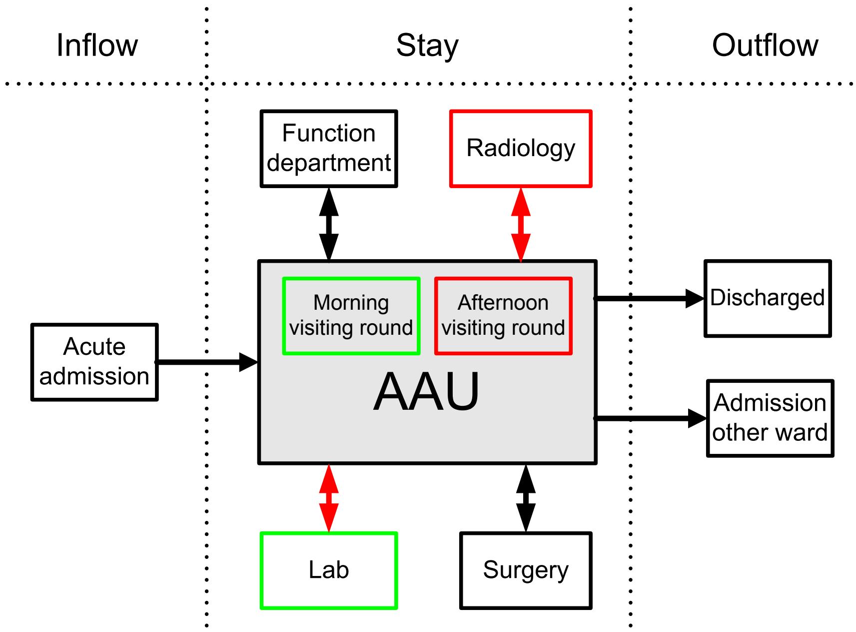

Figure 24: Flow of patients at the AAU plus its performance

In total, there are eight areas in which the performance is lacking, and six of them are visualized in one of the two figures. First one inflow problem will be addressed. The performance analysis has shown that the ED-AAU access time is often longer than the norm. Of the stay phase the following performance problems were found. First of all, the visiting rounds of ACH and ORT are poorly

accompanied by consultants. Second, the afternoon visiting rounds start often too late and the starting time deviates a lot. Furthermore at those afternoon visiting rounds relatively few outflow decisions are taken, which limits the throughput of patients. The relation of the lab with the morning visiting round is the next area of worse performance. At the time the morning visiting round is started too few lab tests of the 9:00 lab round are known. Also the radiology department has difficulties to have the results of the radiology tests available before the next visiting round. This is not only due to the bad linkage of the two department but also due too the long throughput time of radiology tests.
Finally two problems are discussed with regard to the performance of the outflow phase. First, a considerable amount of patients is transferred after 18:00. These transfers cause a higher workload at other departments as anticipated. Second, The flow out time of several patients is very long.

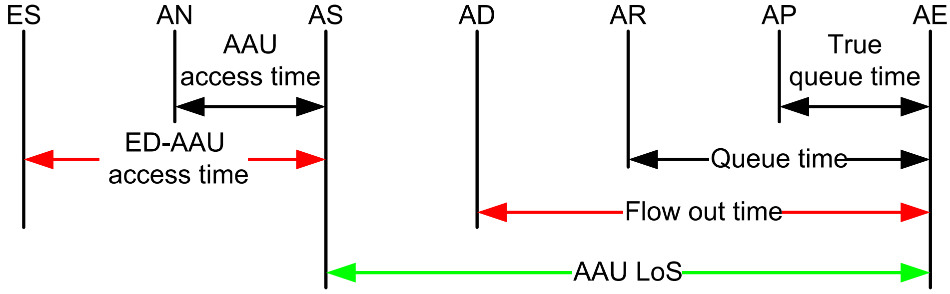

Figure 25: AAU time performance measures plus its performance

Of these problems it has been assessed which problems could be dealt with, taking into account the scale of a master thesis project, the impact of the possible improvement, and the attractiveness of solving the problem. After confer with the supervisors the following three problems were chosen:

- The late evening visiting round at the AAU
- The bad connection of the 8 o'clock lab round with the morning visiting round.
- The lack of insight at the AAU in the number of admissions per day and the resulting large number of transfers after 18:00.

These problems will be dealt with in the next chapter when solutions will be given for these problems.

6 Design

This chapter is the last in a series of chapters in which the main research question and the sub questions were assessed. At this point it is known what the processes look like, what performance measures can be used to assess the performance and what data is needed to assess these performance measures. In the previous chapter all performance analyses were done, which resulted in a lot of new insights, and also showed processes for which improvement is needed. Three problem areas were distilled, and the will be further discussed in this chapter. Here several designs are made for the three problems. These designs should help to improve the performance related to the problems. First, a solution direction is given to eliminate the late evening visiting rounds. The bad link of the morning lab round and the visiting round will be discussed second. Finally, several forecasting models are tested to increase the insight in the inflow of patients at the AAU.

6.1 Late evening visiting round

The performance analysis showed that evening rounds often start too late, see section 5.3.3. This is undesirable for several reasons. First, late evening rounds make a transfer of a patient before 18:00 almost impossible. Six o'clock is an important time for the transfer of patients, because the admission agency at the MMC, who takes care of transfer of patients, takes of at six. If a patient needs to be transferred after six, the AAU nurses have to arrange this, which keeps them away from their other duties. Furthermore, when the AAU was designed it was projected to have no transfers after six. The receiving wards were staffed with this in mind. So all transfers after six, and especially after nine are unwanted. If visiting rounds start late, it is almost impossible to arrange a transfer before six.
Second, late visiting rounds hinder additional tests from taking place before the next visiting round, in particular radiology and function test. If at the evening round is decided that a patient needs another test, it is best if that test is performed as soon as possible, preferably the same day. Then the results are available before morning visiting round start the next day. When visiting rounds are not on time, then almost no time is left to perform additional tests prior to the next visiting round. This jeopardises the total effectiveness and usefulness of the evening visiting round.
A solution for this problem is simple on paper; just make sure the evening visiting rounds are done in time. Only the execution of the plan is more complicated. It has been noticed in practice that most delays are caused by consultants running late. For many consultants the AAU evening visiting round is their last activity. Consultants performed all kinds of activities during the day, e.g. working in the outpatient clinic, performing surgeries, and performing function tests. All these activities have the possibility of taking more time as planned and increase the chance of running late at the AAU evening round. These activities can often not be terminated to ensure a timely evening visiting round; a surgeon who is in the middle of surgery cannot simply step out, and come back an hour later. To overcome this problem a suggestion is done, which could increase the possibility of a timely evening round.
The largest delay in doing visiting rounds is due to previous activities from consultants. When rosters for consultants are made, the AAU evening visiting round should be one of the criteria. Meaning that prior to the AAU evening round the AAU responsible consultant should not perform activities which have a high probability of running late. For instance do not perform surgeries. Another solution is to end these prior activities earlier, so possible delays do not have an effect on the visiting round. This could mean that the consulting hours should be shortened. These solutions would certainly reduce the variation in the start time of AAU's evening visiting round. When improvements are needed in making the outpatient schedule, Jacobson et al. (2006) could be viewed for a short literature review on several outpatient scheduling techniques.

6.2 Connection lab results and morning visiting round

The second problem, for which new design is proposed, is the connection of the 8:00 lab round with the morning visiting rounds. As shown in section 5.3.4, most of the lab results of the 8 o'clock lab round aren't known before most of the visiting rounds have started. This is not desirable, because first of all lab results influence the patient's treatment plan and could cause a delay in patients stay.

Second, doctors need to check the results at a later time, which takes extra time. Therefore the connection of the lab and the visiting round should be improved.
The most simple, and effective, way to increase the probability of having relevant lab results in time is to increase the time between the lab round and the visiting round. To achieve this, two solutions are available: postpone the visiting round or bring the lab round forward. Before the feasibility and impact on current operations of both solutions will be assessed, it is analyzed what the impact is of delaying or advancing the visiting or lab round.
Here it is tested what the result is of bringing forward the lab round with one hour, i.e. how many results of the lab tests would be known before the lab round is started. In Figure 26 this scenario is visualized. When the lab round is brought forward one hour, keeping everything else equal (including the service time) the probability of having the lab results in time increases dramatically. The precise impact is illustrated by the same example as used in section 5.3.4. The fraction of visiting rounds started at 8:30 and 9:00 is compared to the fraction of lab results known. The results for both the current and the designed situation can be found in Table 15. Due to the short service time at the lab, the fraction of tests known before the visiting round starts increases dramatically. The designed situation would be an immense improvement to the link of the lab and the AAU. Now, the best way to gain this improvement will be discussed, first the postponement of the visiting round will be addressed, after that the advancement of the lab round is discussed.

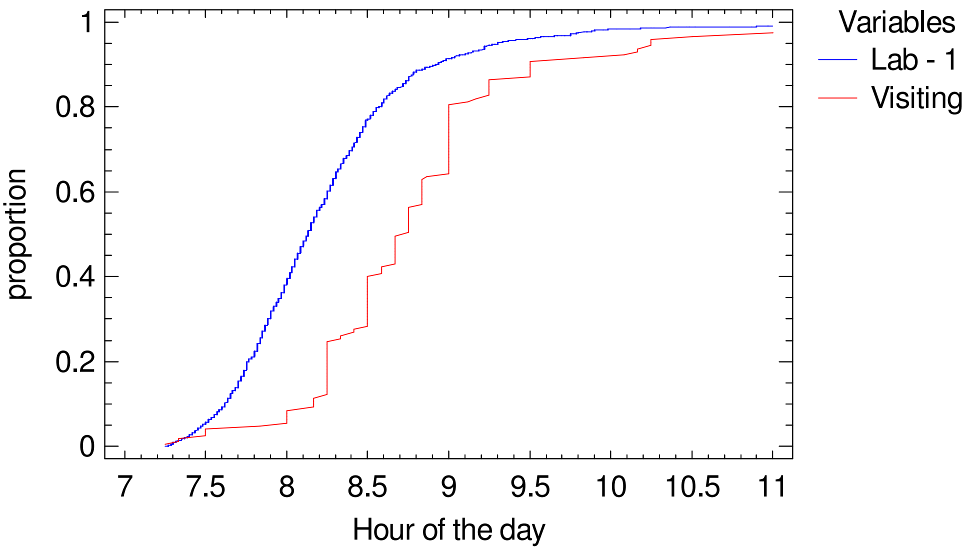

Figure 26: Possible situation of lab results known and visiting times in the morning

If visiting rounds are postponed this would have an impact on both the activities of consultants later that day, and on the planning and execution of tests. Consultants would have to adapt their complete schedule when visiting rounds are postponed. All surgeries, outpatient's clinic appointments and function tests, done by consultants who perform the AAU morning visiting should also be postponed. This would of course have a large impact on many processes in the hospital. And planning and executions of test will also be influenced when visiting rounds are postponed. All requests for additional diagnostic tests or treatment will be submitted later. This makes the planning of these tests and treatment more difficult. This could result in a later execution of these tasks, with its own consequences. All in all the postponement of the AAU morning visiting has many downsides and is not the right solution to the problem. The other option, bringer the lab round forward, is discussed next.
In case the lab round is brought forward one hour, the samples must be gathered and analyzed one hour earlier. So as early as 7:00, lab samples must be gathered. This implies that lab personnel should start earlier to be ready to gather the samples at 7:00. Another solution is that AAU personnel gather the samples, which is also done at specialized wards like the IC. The downside of this solution is that AAU nurses' workload is increased, and they have to gather the samples around the nurses transfer (7:00-7:15), which is already a busy time. Both solutions have its downsides, and would require some adaption of both lab and AAU personnel.

A second, more complex, but also effective way to increase the probability of having relevant lab results in time is to put the characteristics of both processes in full use. From Figure 17 it is known that not all morning visiting rounds of the different specialties start at the same time. For instance ACH doctors start their visiting rounds often before INT doctors do. When the lab would use the medical specialty to prioritize the processessing of samples, so processing ACH AAU samples before INT AAU samples, even more lab results can be finished in time. This solution is more complex, since lab personnel should distinct between the samples based on their medical specialty, and is not as effective as advancing lab rounds or delaying visiting rounds, but it does seem a good addition to the other advancing the lab rounds.
The best solution to the bad link of the 8:00 lab round with the morning visiting round would be to bring the lab round forward, since the postponement of the visiting round has too much unwanted side effects. However, it is not straightforward how to solve this issue. Furthermore the prioritizing of samples from certain specialties would be a good addition to bringing the lab rounds forward. The AAU and the lab should take these findings and conclusion into consideration and need to decide what the best and for both parties acceptable, course of action is to improve the connection of the morning lab and visiting round.

Table 15: Comparison of current and designed lab/AAU connection

Time	Fraction visiting rounds started	Fraction lab results known	
		Current	Design
8:30	0.40	0.10	0.77
9:00	0.80	0.40	0.91

6.3 Lack of insight in inflow of patients

The third area, for which a design is made to improve AAU's performance, is the lack of insight in the inflow of patients. In the inspected period many patients were transferred after 18:00. Since in principal no patients can be transferred from the AAU after 18:00, but patients still flow in at the AAU, the AAU needs to know how many patients will flow in after 18:00. Then the AAU can release beds, by discharging or transferring AAU patients, to ensure its receiving function. When little is known about the number of inflowing patients, it is hard to predict the right number of beds to preventively release. If the prediction of inflowing patients at the AAU can be improved, it is likely the number of transfers after 18:00 will decrease.
In the present situation, a prediction of the number of inflowing patients in the evening and night is used. However, this prediction first of all lacks precision since the prediction is rarely updated. Furthermore the prediction does not use the properties of the system like lower inflows in weekends. Because of that, the prediction is not reliable enough to use. Here it is investigated if the forecast can be improved, to reduce the number of transfers after 18:00. Before a new forecasting method is introduced, first the inflow of patients is analysed. In section 5.2.1 the number of admissions was assessed, per month, week, day and hour. This analysis showed a stable inflow of patients on a weekly basis, differences in inflow per day of week, a statistical significant difference between the number of weekend and weekday admissions, and a high variation in the hourly inflow. Not all insights can be used here, because here a different selection for the days is used. Earlier in this report the inflow was assessed per day from 0:00 to 23:59, here the inflow of patients is assessed from 9:00 to 9:00 the next day. This time period has been chosen, because the AAU in principal cannot transfer patients after 18:00 till the next morning around 9:00. So the inflow most be assessed till 9:00 the next morning. Furthermore these new daily division has been subdivided into two time blocks. The blocks are 9:00-16:00, the so called day block, and 16:00-9:00, the so called night block. The most important sub-block is 16:00-9:00, since there capacity problems arise. The choice for 16:00 was made to allow the information on the number of admissions to be used during visiting rounds. When before the visiting round is known how many patients will flow in, i.e. how many beds are needed, consultants can possibly influence the transfer of patient. By discharging patients earlier or by transferring them sooner, beds can be made available.
Since this division into periods differs from the already analysed time phasing, several analyses need to be redone. Furthermore new data is used to determine the number of admissions per day, now data

is used from September 1, 2008, to February 16, 2009. It is checked here if the number of inflowing patients per week still has a low variation and the differences between the inflowing days still exist. There is no need to repeat the hourly inflow analysis, since the hourly analysis will be very similar. The results of the analyses done, for the weekly and daily inflow, can be found in Appendix AA. It is concluded that that the weekly and daily inflow is in general alike the earlier performed analysis. There are however some differences regarding the fraction of admissions per day of the week, these numbers do deviate somewhat from earlier analysis, but the differences between weekdays and weekends still exists.

In the same appendix, Appendix AA, the statistics are shown for fraction of patients in the new day and evening time blocks. On average 35% of the patients is admitted during the day (9:00-16:00), with a relatively high variation, CV=35%. The averages of the fractions per day show some differences among the days, with a low of 31% day inflows on Saturday and Tuesday, and a high of 39% on Monday. So there exist large differences between days of the week and between the different weeks.

Before the forecasting model is introduced, it is first inspected if a relation exists between the inflows during the day and during night, and if there is a relation between the number of admissions per day of the week. These possible relations can aid in determining the number of admissions per day and time period.

First, it is investigated if the number of admissions per day of the week are related to each other. Since the number of admissions per week do not vary much, but the number of admissions per day of the week do, there could be a relation between the different days. This has been tested by assessing the scatter plots of all possible combinations of the number of admissions per day of the week, see Appendix AA. When the number of admissions of the different days of the week have a relation, a pattern should emerge in one of the plots. This is however not the case, so no relation has been found between the number of admissions per day of the week within the same week. The second relation that could be present and could increase the accuracy of predicting the number of admissions per day of the week is the relation between the number of day and night admissions. One of the reasons for choosing the time blocks is because the predictive power the day block could have for the logistically more important night block. For this analysis also a scatter plot has been used, see the last figure in Appendix AA. The plot also shows no apparent relation. This shows that there is no identifiable relation between the number of day and night admissions. Since there is no relation between the number of day and night admissions there is no need to predict the number of admissions per time block, it is better to predict the number of admissions per day. Then the variation in the number of admissions is relatively lower, which results in a better prediction.

One way to determine the number of beds that need to be available at the AAU in order to safeguard the incoming flow of patients is using newsboy equations. Newsboy equations are used to find the optimal number of e.g. newspapers to buy on a day, given an underage cost, associated with demand that cannot be met, an overage costs, associated with each copy that is not sold, and the underlying distribution of the demand. The similarity with the AAU is that the forecasted number of admissions per day is the same as the number of newspaper to buy. When the number of admissions is forecasted too low, too few beds are made available, which will most likely result in late night transfers of patients. When the number of admissions is forecasted too high, too many beds are made available at the AAU, and several beds will not be utilized. Both scenarios are not wanted since both scenarios will result in extra costs.

The questions that need to be answered here are: what are the costs for the excess of beds, i.e. what are the costs of a bed staying empty all night, and what are the costs for a shortage of beds, i.e. what are the costs of a late night transfer (Silver et al., 1998). Unfortunately, both costs are very difficult to determine since both cannot be determined unambiguously. First, the costs of a bed staying empty at the AAU will reduce AAU's income, since the bed was made available by either transferring or discharging a patient. But keep in mind that discharging a patient is not reducing AAU's income it is reducing patient's costs for its hospital stay in a medically responsible manner. And keep in mind that transferring a patient is reducing AAU's income, but is not likely to result in lower income for the hospital as a whole, as long as no elective admissions needed to be cancelled. Second, having too few beds available and therefore needing to transfer patients after 18:00 will cause extra workload after 18:00. This can be resolved by adding extra staff. However the relation of having transfers after 18:00

and adding personnel is not straightforward; what are the extra costs for having one transfer more after 18:00? Since both costs for having too many or too few beds are unclear, the forecast of the number of admissions i.e. the number of available beds needed, is not based on costs.

Newsboy equations determine the optimal number of, in this case, number of admissions per day i.e. the number of beds needed to be available, based on the under- and overage cost by determining with what probability all demand should be met. With the use of the underlying statistical distribution the optimal number can be calculated. Since the under- and overage cost cannot be determined fairly, the optimal solution cannot be determined. Therefore it was chosen to use different solutions to show the variation in the most likely range.
In section 5.2.1 it was found that the number admissions differ per day of the week, therefore the number of admissions are forecasted per day of the week. Since the number of admissions are normally distributed for each day of the week, the calculation to determine the number of beds that need to be made available, Q, is: $Q = \mu + k\sigma$;with k selected such that $p_{u \geq (k)} = 0.80$ (the notation of Silver et al. (1998) is used). The fraction of 0.8 is used here is an example; k is determined such that with a probability of at least 80% all admissions are covered. Meaning that Q number of beds need to be available that day to safeguard with an 80% certainty a bed for all incoming acute patients at the AAU. Depending on the number of already empty beds, the number of transferred and discharged patients during the day, the AAU can determine how many additional patients need to be discharged or transferred before 18:00 to safeguard the inflow of patients.
Analysis on the outflow of patients in the period September-November has shown that about 10% of all patients left the AAU after 18:00.. If these numbers are literally interpreted it means that in general 10% of all AAU patients were transferred for logistical reasons. So when the Newsboy equation is used a probability of 90% seems logical. However, one needs to keep in mind that at weekends practically no transfers take place after 18:00, which means that the fractional transfers after 18:00 for weekdays is much higher. Therefore also some smaller values than 90% have been chosen. In total four percentages, 75, 80, 85 and 90 have been used. These percentages will be used to determine the number of beds that need to be made available each day.

Table 16: Number of admissions at the AAU per day per probability

			Number of admissions with the following probabilities			
Day of the week	μ	σ	0.75	0.8	0.85	0.9
Monday	23.08	4.25	26	27	28	29
Tuesday	18.96	5.44	23	24	25	26
Wednesday	20.54	5.08	24	25	26	28
Thursday	17.67	5.55	22	23	24	25
Friday	20.67	5.16	25	26	27	28
Saturday	14.50	4.64	18	19	20	21
Sunday	13.42	3.61	16	17	18	19

The results of the calculations for all probabilities per day of the week are given in. For example, when the AAU wants to be able to safeguard the incoming flow of patients on a Monday, with a certainty of 80%, one should have in total 27 beds available. Since many patients arrive at the AAU after the afternoon visiting round, the bed utilization is low around that time, and there is additional time to transfer patients before 18:00, the afternoon visiting round is a key moment to see if additional beds need to be freed. With the afternoon visiting rounds, it is best to balance the number of the to be outflowing and inflowing patients and see if any additionally patients need to be transferred for logistical reasons. By using the prediction of the number of admission per day of the week, the AAU can limit the number of transfers after 18:00 best .
Table 16 shows that the number of admissions has increased in comparison to the period September-November. This means that during December, January and February, more patients were admitted.

For the calculated fractions it could mean that the forecasts are low, since also the admissions in September-November are taken into account. Furthermore, literature has shown that the number of admissions at EDs are influenced by several factors: weekly and yearly patterns, holidays and near holidays, climate variables, influenza illness rates (Morzuch & Allen, 2006; Jones et al., 2002; Jones et al., 2008; Upshur et al., 2005). Since the AAU shares numerous properties with the ED, it is important to reflect on those aspects in the future. It is somewhat difficult to use climate variables and influenza illness rates, but yearly patters, holidays and near holidays can be taken into account in the future to make the prediction more accurate. Concerning the yearly pattern, it is now too early to tell if the increase in admissions during December-February is due to seasonal patterns, or due to a trend.

The AAU should use these fractions to forecast the number of admissions per day. These numbers should then be used to transfer or possibly discharge patients earlier during the day, at least before 18:00, to reduce the number of (unwanted) transfers after 18:00. When these numbers are used strictly the AAU will end up with empty beds. Since the costs cannot used to determine the optimal number of admissions per day is, the AAU should self determine which fraction of admissions they certainly want to accept at the AAU, without the need for late night transfers.

7 Conclusion and recommendations

This final chapter of the report will be used to look back at all previous chapters. In this chapter, the general conclusions of this research will be given first. This will be followed by a discussion of the limitations of this report. After hat, recommendations are given for MMC to improve the performance of the AAU. This chapter will be concluded with directions for future research within MMC.

7.1 Conclusions

The research question for this master thesis project was expressed in section 1.3 as:

What improvements need to be made and/or rules need to be set for the acute assessment unit to ensure a robust system that can ensure its intended performance and benefits?

With the use of seven research questions, an answer has been gathered to the research question. In total three concrete improvements have been suggested to improve the performance of the AAU. First, the evening visiting rounds should be done in time, so doctors' schedules should take into account the evening visiting round at the AAU. This enables the execution of additional tests before the next visiting round. Hereby more information is available about the patients' condition and patients can possibly leave the AAU sooner. Second, the 8:00 lab round should have a better link with the 9 o'clock visiting round. By for instance advancing the lab round with one hour, the probability of having the lab results in time, increases dramatically. This reduces rework for doctors, and could reduce the length of patients' stay at the AAU. The third and final improvement is increasing the insight in the number of admission at the AAU with the use of forecasting techniques. By having more insight in the number of admissions, the AAU can actively increase the number of out flowing patients before patients are really admitted. This reduces the unwanted evening transfers and transforms the AAU form being re-active to being pro-active.

Next to these three main findings also understanding was established in the properties of AAU's processes. Some of these insights have led to recommendations which will be discussed in the third section of this chapter

7.2 Limitations

The results discussed in this master thesis have some limitations. The first limitation has to do with the inspected period. The analyses done in this report are based on the data of September till October. By now it is March and twice as much data is available. The new data could lead to new understanding. From practice and from assessing the forecasting models, it is known that December and January were busy months, which has resulted in even higher utilization levels. This means that this report is already out-dated; however this report does give lots of understanding in the properties of the AAU, and especially in the relation of the AAU with other departments. When improvements are made in these areas the AAU will become more capable to react to higher number of admissions. Yet, this does not mean that the new data should be ignored, especially in the beginning new data is crucial to gain more insight.

Another limitation of this study is that although with the set-up of the performance measures all relevant performance measures, coming from different dimensions, were used, not all performance can be captured in measures, or obtained form the inspected data. One aspect that could not be captured in the data, but which was mentioned numerous times by doctors, is the bad communication between AAU nurses and doctors concerning the transfer of patients. Often, the responsible doctors aren't informed about the transfer of their patient and to which ward the patient is transferred.

Furthermore this report also does not reflect on the hard work of all nurses and doctors to improve the AAU and deal with all starting up problems. During the period this research was conducted, many practical improvements were made at the AAU. These improvements have resulted in better working conditions which aren't captured in this report.

So in general this report reflects on much of the aspects of performance at the AAU, but certainly not all aspects have been treated.

7.3 Recommendations

The recommendations are discussed here. The first recommendations follow directly from the design:

- Review the planning of consultants who do the AAU visiting rounds carefully. Prevent as much as possible the influence other activities have on the AAU visiting round.
- Arrange a meeting between the AAU and the Lab in which different solutions are discussed to improve the connection of the morning visiting round with the 8:00 lab round
- Use the forecast method made to predict the number of admissions per day and to know how many beds need to be made available that day to safeguard new AAU admissions.

Beside these already discussed recommendations, there are also recommendations that follow explicit but also implicit from this report. These are:

- Critically review the objectives of the number of patients discharged per specialty. The objectives are not equally difficult for all specialties.
- Judge carefully which patients are eligible for transfer and for which patients it is better to stay longer at the AAU. This could reduce the number of transfers to wards.
- Make sure that the all consultants attend both visiting rounds at the AAU.
- When the nurses planning of the AAU is made, it could be beneficial to critically review the bed utilization per day of the week. This could lead to changes in the roster. Not necessarily by reducing staff at days with a lower utilization, but by enabling non-patient care related activities on these days.
- In due time when tests are requested digitally, the systems should enable the registration of the time of this request. Then a lot of useful information will become available, and the performance of the different tests can be assessed even better.

7.4 Further research

In this report many different analyses were done, but still there are some areas in which further research could increase the insight of the processes. Here these areas are listed.

When the problem situation was introduced the search for the right number of beds at the AAU was introduced: How many beds should the AAU have, to function properly. In this report no indication was found that the number of beds at the AAU is not sufficient. However, when the data of the months December and January are considered, this conclusion changes, In December and January are days with 32 admissions. On those days the AAU is forced to free all beds to be able to admit new patients. This suggests that it is necessary to increase the number of beds. Therefore it is recommended if MMC uses this report as background knowledge about their AAU, and uses all available data to best determine the number of beds needed at the AAU.
Beside the number of beds also the available beds at normal wards should be assessed. In this report it was shown that for several patients it took a while before they could be transferred to normal wards, possibly because no appropriate bed was available. So it should be investigated how the outflow of patients to the wards can best be guaranteed.
In the design section, different models were assessed to forecast the number of admissions per day. It was found that the different models did not perform well enough due to increasing numbers of admissions. The different models can be used, but lack precision. Therefore it is best if the AAU will reflect on these models around September 2009, to see if the addition of any seasonal, or trend to the models will improve the explanatory power. This could also aid in selection selecting the right number of beds at the AAU and at the other wards to guarantee a bed for transferred patients.
Apart from analysis at the AAU, it would also beneficial of the performance at all MMC's wards to deeper analyse the performance at the lab and at the radiology department. Extra analysis is needed at the lab to see how the performance of the CITO tests can be improved. Improvements at the radiology are possible regarding the reporting of tests. Furthermore if all time moments discussed in the performance measurement section, are available, a more comprehensive analysis of the radiology department can be made, and possibly more areas for improvement can be found.

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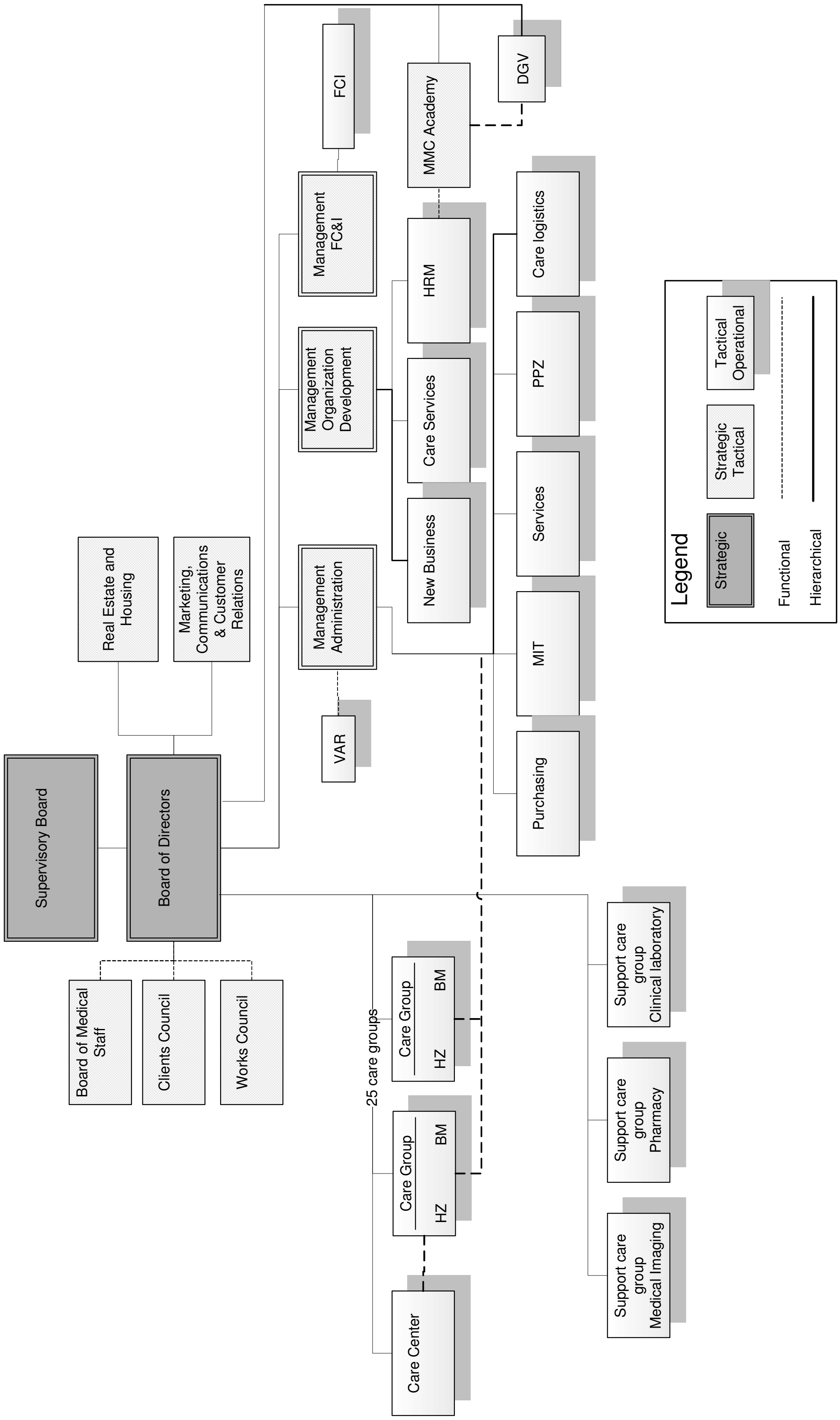
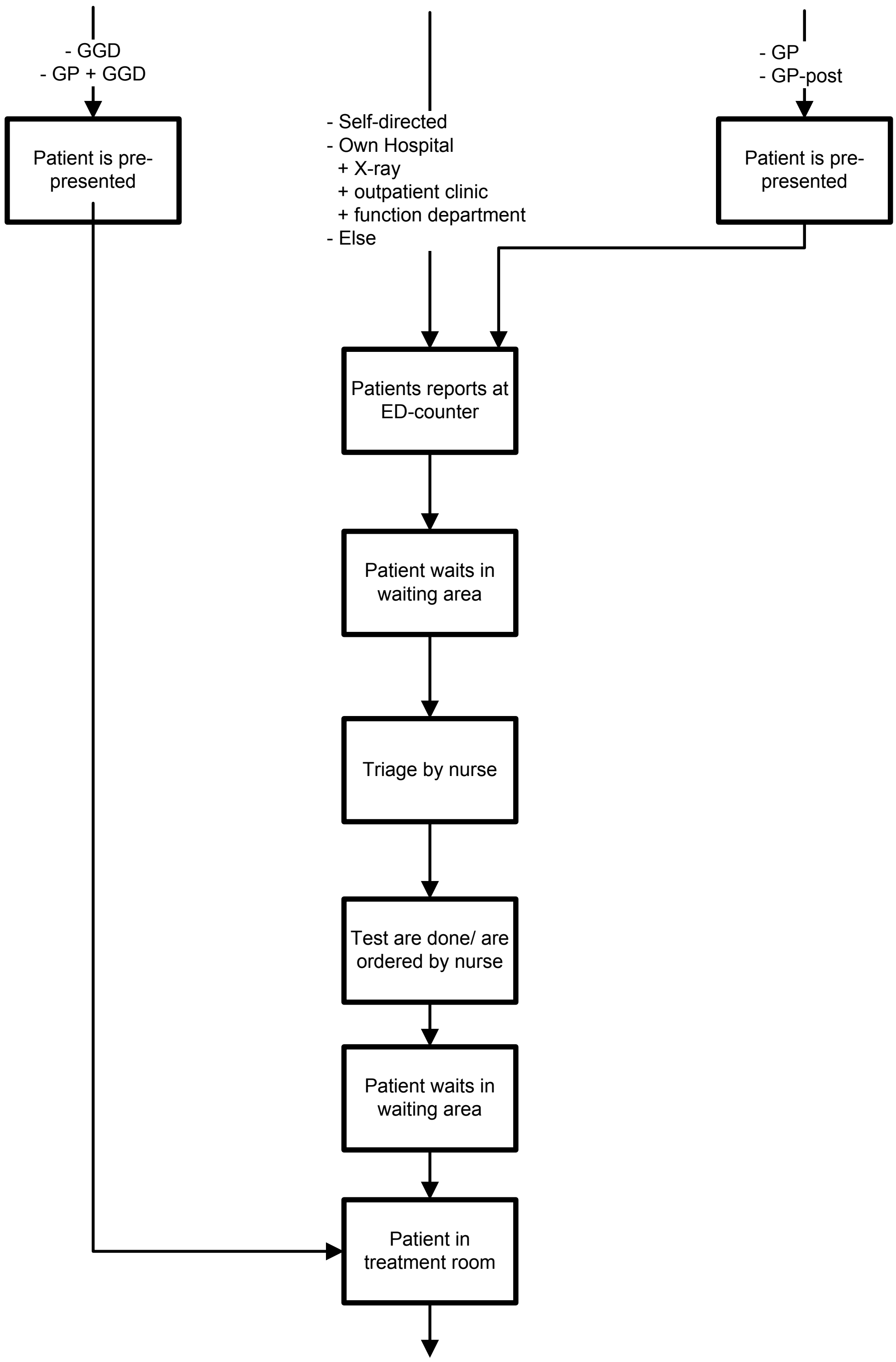
List of abbreviations

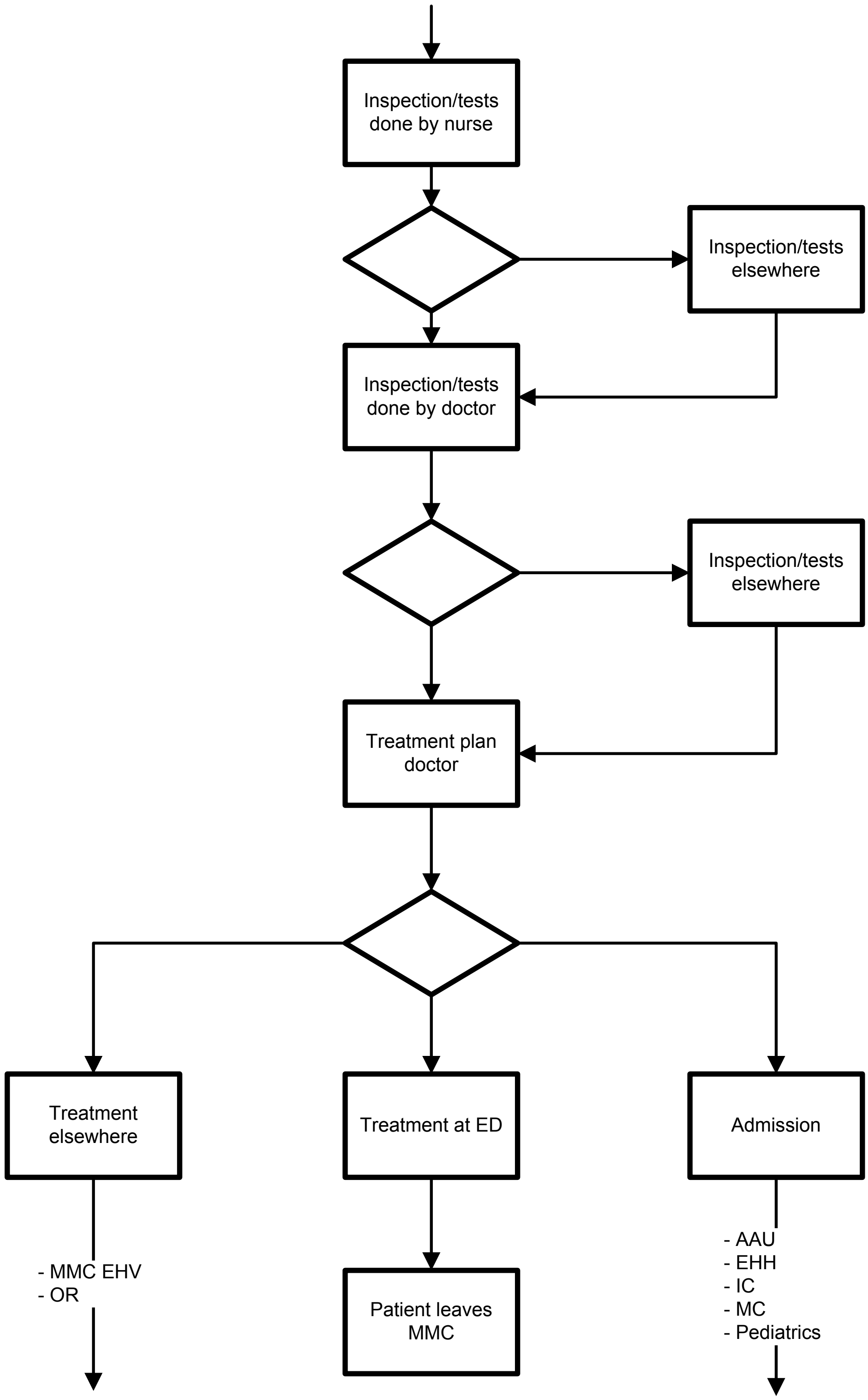
Abbreviation	Explanation
AAU	Acute Admissions Unit
ACH	General Surgery
CAR	Cardiology
CC (U)	Coranary Care (Unit)
CS-EZIS	“Dutch: ChipSoft – Elektronisch Ziekenhuis Informatie Systeem”
CS-OK	“Dutch: Chipsoft – Operatie Kamer”
CS-SEH	“Dutch: ChipSoft – Spoed Eisende Hulp”
CV	Coeffecient of Variation
ED	Emergency Department
EHH	First Coronary help (Dutch: “Eerste Hart Hulp”
EHV	Eindhoven
FTE	Full-Time Equivalent
GGD	“Dutch: Gemeentelijke Gezondheids Dienst”
GP	General Practitioner
IC (U)	Intensive Care (Unit)
INT	Internal Medicine
Lab	Laboratory
LoS	Length of Stay
MC (U)	Medium Care (Unit)
MDL	Gastroenterology
MMC	Máxima Medical Centre
NEU	Neurology
OR	Operation Room
ORT	Orthopaedic surgery
PUL	Pulmonology
URO	Urology
VHV	Veldhoven

Appendix A Organization diagram of MMC

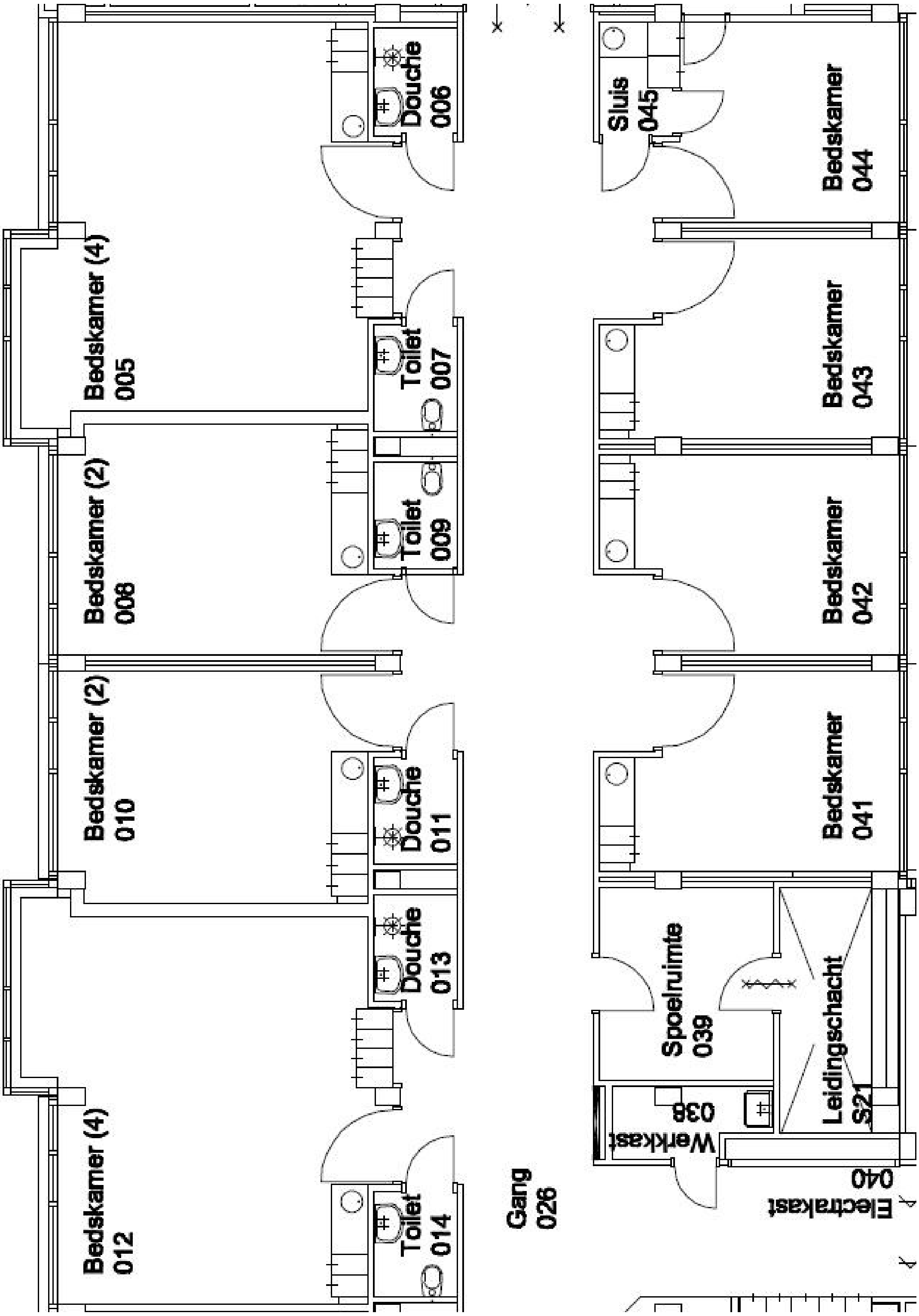


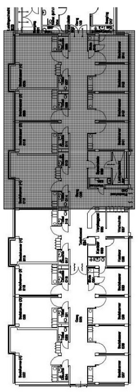
Appendix B Patient flow at the ED

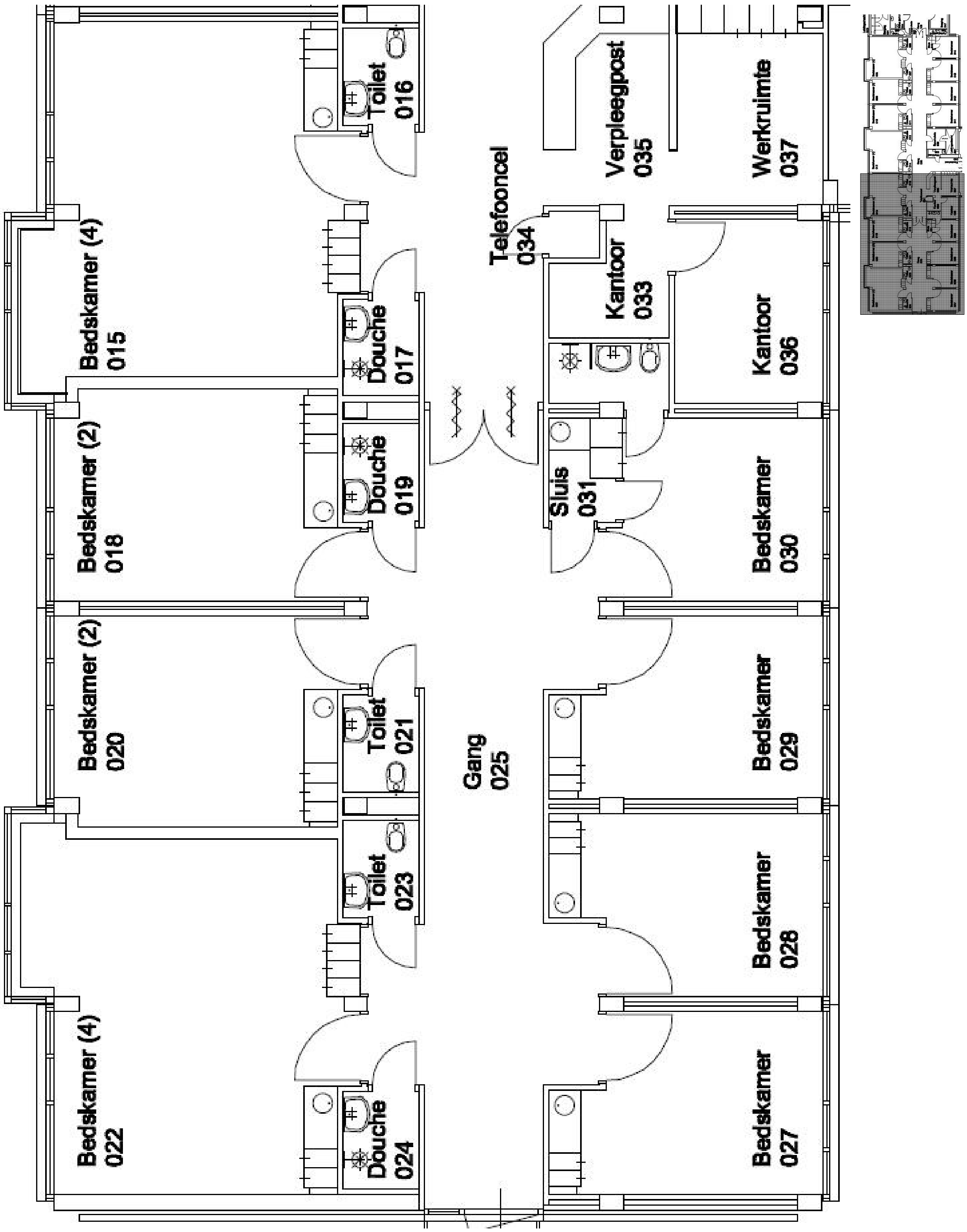



Inspection/tests done by nurse
Inspection/tests elsewhere
Inspection/tests done by doctor
Inspection/tests elsewhere
Treatment plan doctor
Treatment elsewhere
Treatment at ED
Admission
- MMC EHV
- OR
Patient leaves MMC
- AAU
- EHH
- IC
- MC
- Pediatrics

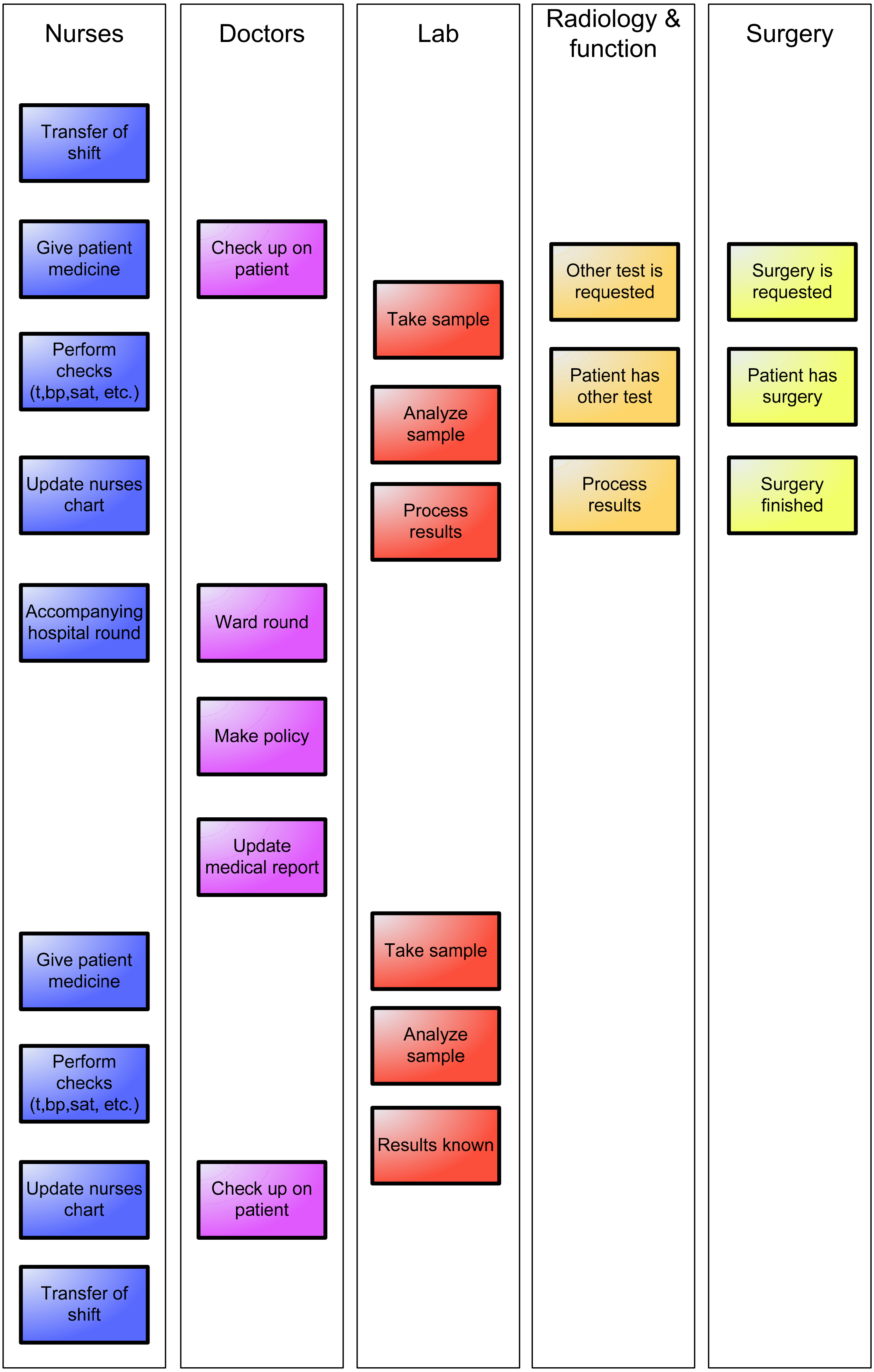
Appendix C Blueprint AAU






Toilet 016
Verpleegpost 035
Werkruimte 037
Telefooncel 034
Bedskamer (4) 015
Kantoor 033
Kantoor 036
Douche 017
Bedskamer (2) 018
Douche 019
Sluis 031
Bedskamer 030
Bedskamer (2) 020
Toilet 021
Gang 025
Bedskamer 029
Toilet 023
Bedskamer 028
Bedskamer (4) 022
Douche 024
Bedskamer 027

Appendix D Processes during the stay phase at the AAU



Appendix E Goals of percentage of discharge within x hours for AAU patients

LMR MMC 2006	Ligduurklasse klinische opnamen							
Heelkunde	1 dag	2 dagen	3-5 dagen	6-10 dagen	11-16 dagen	17-30 dagen	31 - 99 dagen	100 dagen of meer
% ontslag acute opnamen 2006	11%	19%	30%	21%	10%	5%	4%	0%
cumulatief % ontslag 2006	11%	30%	60%	81%	90%	96%	100%	100%
AoA cumulatief % ontslag	**20%**	**50%**	**65%**	85%	92%	97%	100%	100%

LMR MMC 2006	Ligduurklasse klinische opnamen							
Interne Geneeskunde	1 dag	2 dagen	3-5 dagen	6-10 dagen	11-16 dagen	17-30 dagen	31 - 99 dagen	100 dagen of meer
% ontslag acute opnamen	8%	12%	24%	29%	13%	10%	4%	0%
cumulatief % ontslag	8%	20%	44%	73%	86%	96%	100%	100%
AoA cumulatief % ontslag	**15%**	**30%**	**50%**	75%	88%	97%	100%	100%

LMR MMC 2006	Ligduurklasse klinische opnamen							
Longgeneeskunde	1 dag	2 dagen	3-5 dagen	6-10 dagen	11-16 dagen	17-30 dagen	31 - 99 dagen	100 dagen of meer
% ontslag acute opnamen	4%	8%	20%	36%	18%	11%	3%	0%
cumulatief % ontslag	4%	12%	32%	67%	86%	97%	100%	100%
AoA cumulatief % ontslag	**10%**	**30%**	**40%**	70%	90%	98%	100%	100%

LMR MMC 2006	Ligduurklasse klinische opnamen							
MDL	1 dag	2 dagen	3-5 dagen	6-10 dagen	11-16 dagen	17-30 dagen	31 - 99 dagen	100 dagen of meer
% ontslag acute opnamen	6%	12%	28%	29%	12%	9%	4%	0%
cumulatief % ontslag	6%	19%	47%	76%	87%	96%	100%	100%
AoA cumulatief % ontslag	**10%**	**30%**	**55%**	80%	90%	97%	100%	100%

LMR MMC 2006	Ligduurklasse klinische opnamen							
Orthopedie	1 dag	2 dagen	3-5 dagen	6-10 dagen	11-16 dagen	17-30 dagen	31 - 99 dagen	100 dagen of meer
% ontslag acute opnamen	10%	21%	19%	21%	13%	11%	5%	1%
cumulatief % ontslag	10%	31%	50%	71%	84%	95%	99%	100%
AoA cumulatief % ontslag	**20%**	**45%**	**55%**	75%	85%	95%	99%	100%

LMR MMC 2006	Ligduurklasse klinische opnamen							
Urologie	1 dag	2 dagen	3-5 dagen	6-10 dagen	11-16 dagen	17-30 dagen	31 - 99 dagen	100 dagen of meer
% ontslag acute opnamen	6%	17%	43%	26%	3%	4%	1%	0%
cumulatief % ontslag	6%	24%	66%	92%	95%	99%	100%	100%
AoA cumulatief % ontslag	**10%**	**30%**	**70%**	95%	96%	99%	100%	100%

Appendix F Variables are used for the following data overviews

	AN_j	AS_j	AD_j	AP_j	AR_j	AE_j	ES_j	HS_j	HE_j	$TN_{i,j,k}$	$TP_{i,j,k}$	$TS_{i,j,k}$	$TE_{i,j,k}$	$TR_{i,j,k}$	$HR_{s,d}$	S_j
General data AAU and Ward	X	X				X		X	X							X
Detailed data AAU			X	X	X										X	
Function department																
ED							X									
Lab											X	I	X	X		
Radiology										I			I	X		
Surgery												X	X			

Appendix G Data gathering forms AAU

Start tijd van visite lopen per specialisme **week 48**

	maandag 24-nov				dinsdag 25-nov				woensdag 26-nov				donderdag 27-nov			
	ochtend		middag		ochtend		middag		ochtend		middag		ochtend		middag	
	tijd	h-beh	tijd	h-beh	tijd	h-beh	tijd	h-beh	tijd	h-beh	tijd	h-beh	tijd	h-beh	tijd	h-beh
ACH																
INT																
LONG																
MDL																
NEU																
Ortho																
URO																
anders																

Start tijd van visite lopen per specialisme **week 48**

	vrijdag 28-nov				zaterdag 29-nov				zondag 30-nov			
	ochtend		middag		ochtend		middag		ochtend		middag	
	tijd	h-beh	tijd	h-beh	tijd	h-beh	tijd	h-beh	tijd	h-beh	tijd	h-beh
ACH												
INT												
LONG												
MDL												
NEU												
Ortho												
URO												
anders												

Afdelingsoverzicht AOA

Kamer/B		Naam	Geb.dat	G.	Opnamenr	Behandelaar	Opn.dat	Ontslag/overpl. besl.tijd	Tijd overpl. Afd. bekend (opname)	geplande tijd overpl. (afdeling)
133	1	Diepeveen, B.A.W.	18-12-1983	M	123456	Verhagen, L.	28-11-2008	9:00	10:00	14:30
134	1		- -				- - :			
	2	################	##########	#	########	################	29-11-2008			
	3	################	##########	#	########	################	29-11-2008			
	4		- -				- - :			
135	1	################	##########	#	########	################	30-11-2008			
136	1	################	##########	#	########	################	29-11-2008			
	2	################	##########	#	########	################	28-11-2008			
137	1	################	##########	#	########	################	28-11-2008			
138	1	################	##########	#	########	################	28-11-2008			
	2	################	##########	#	########	################	30-11-2008			
139	1	################	##########	#	########	################	29-11-2008			
140	1	################	##########	#	########	################	30-11-2008			
	2	################	##########	#	########	################	29-11-2008			
	3	################	##########	#	########	################	29-11-2008			
	4	################	##########	#	########	################	28-11-2008			
141	1	################	##########	#	########	################	28-11-2008			
142	1	################	##########	#	########	################	28-11-2008			
	2	################	##########	#	########	################	30-11-2008			
	3	################	##########	#	########	################	28-11-2008			
	4		- -				- - :			
143	1	################	##########	#	########	################	29-11-2008			
144	1	################	##########	#	########	################	28-11-2008			
	2	################	##########	#	########	################	28-11-2008			
145	1	################	##########	#	########	################	28-11-2008			
146	1	################	##########	#	########	################	29-11-2008			
	2	################	##########	#	########	################	28-11-2008			
147	1	################	##########	#	########	################	28-11-2008			
148	1	################	##########	#	########	################	28-11-2008			
	2	################	##########	#	########	################	30-11-2008			
	3		- -				- - :			
	4	################	##########	#	########	################	30-11-2008			
Zadm	1		- -				- - :			
	2		- -				- - :			
	3		- -				- - :			
	4		- -				- - :			
	5		- -				- - :			

Datum: **30-11-2008 7:03**

Appendix H Manual to create customized AAU occupation overview

Handleiding voor het maken van een AOA overzicht voor dataverzameling Bob

1. Open in EZIS het afdelingsbezettingsoverzicht van de AOA

2. Kopieer dit overzicht:
   a. Klik in het overzichtsscherm op de rechtermuisknop
   b. Kies de optie: *"alles selecteren"*
   c. Druk tegelijkertijd op *"Ctrl"* en *"c"* (hiermee kopieer je het hele overzicht)

3. Open het Excel bestand genaamd: "AOA overzicht.xls"
   a. Dit bestand staat in: Mijn documenten → AOA → Studenten AOA → Bob

4. Kies bij de beveiligingswaarschuwing voor: "Macro's inschakelen"

5. Selecteer het tabblad: "invullen" (dit kan je kiezen onderaan in het scherm, Let op dit tabblad is leeg)

6. Selecteer de cel: A1. (dit is de cel in de linker bovenhoek)

7. Druk tegelijkertijd op *"Ctrl"* en *"v"* (hiermee plak je het hele overzicht)

8. Druk tegelijkertijd op *"Ctrl"* en *"q"* (hierdoor wordt het overzicht gemaakt)

9. Wacht een tweetal seconden

10. Het dagoverzicht is nu gemaakt en staat klaar

11. Print dit overzicht

12. Sluit het Excel bestand af zonder op te slaan

Appendix I Altered admissions

Altered admissions (first type of error)	Altered admissions (second type of error)
907245	930933
918004	920081
923472	920346
924093	922349
926565	924526
926673	925354
927020	925594
928964	926933
929250	927003
929406	927667
930632	928540
931084	918360
931443	929631
932524	936416
933511	931277
933551	931335
935267	931613
	933029
	933059
	934295
	934499
	935184
	935727
	935973
	936073
	928606

Appendix J Included types of lab tests

Makey	Description
AF	Alk. Fosf.
AGLU	Gluc. a.l.v.
ALAT	ALAT
ALB	Albumine
ALBU	Albumine U
AMMO	Ammoniak
AMYL	Amylase
AMYU	Amylase U
APHP	APTT-heparin
APTT	APTT
ASAT	ASAT
ATAC	Antitrombine
ATAM	Amylase
ATE	Eiwit alv
BAEX	Base excess
BART	Materiaal
BDAG	DAT
BGR	BGR Result
BICA	Bicarbonaat
BILD	Bili geconj.
BILE	Bili-excess:
BILI	Bili totaal
BILL	Bili liquor
BSE	Bezinking
BSEL	IAT
CABG	Calc. geion.
CACR	Calcium corr
CAL	Calcium
CHHD	Chol/HDLchol
CHOL	Cholesterol
CK	CK
CKM	CK-MB mass
CL	Chloride
CO2T	Bicarbonaat
COHB	CO-Hb
CPAR	Paracetamol
CRP	CRP
DDIM	D-dimeer
ERY	Erytrocyten
FE	IJzer
FIB	Fibrinogeen
FOS	Fosfaat
FT4	FT4
GEND	Gentam. dal
GENT	Gentam. top
GGT	gamma-GT
GL08	Glucose 08u
GL11	Glucose 11u

Makey	Description
GLBG	Gluc(bldgas)
GLL	Glucose L
GLMO	Glucose
GLN	Glucose nuch
GLQ	Glucose Quot
GLW	Glucose
GRAV	Zwanger.test
H140	APTT
H142	PT
H150	Fibrinogeen
HB	Hemoglobine
HBBG	Hb (bldgas)
HDLC	HDL-cholest.
HPGL	Haptoglobine
HT	Hematocriet
INR	INR
K	Kalium
KEI4	Albumine U
KKET	Ketonen U
KKLA	Klaring
KKRE	Kreatinine
KNIT	Nitriet U
KR24	Kreat/24 U
KREA	Kreatinine
KRUR	Kreatinine U
KU	Kalium U
KVOL	Volume urine
LACL	Lactaat L
LACT	Lactaat
LALB	Albumine L
LD	LD
LDLC	LDL-cholest.
LDR	LD-ratio
LEU	Leukocyten
LI08	Kernh.cellen
LI09	Erytrocyten
LTE	Eiwit liquor
MAL	Mal.sneltest
MALB	mAlbumine U
MALD	Mal.dif
MALI	Malaria info
MALS	Malaria type
MCH	MCH
MCHC	MCHC
MCV	MCV
METHB	MetHb
MG	Magnesium
MTHB	MetHb

Makey	Description
NA	Natrium
NAU	Natrium U
NBNP	NT-proBNP
NEUA	Neutrofiel #
O2SA	O2 saturatie
OSMO	Osmolaliteit
OSMU	Osmolalit. U
PARC	Paracetamol
PCO2	pCO2
PH	pH
PO2	pO2
PT	PT
RDW	RDW-CV
SOP3	Erycurve
SOPM	Microsc. U
TE24	Eiwit/24 U
TFST	Transf.verz.
TRFE	Transferrine
TRIG	Triglycer.
TRO	Trombocyten
TRO12	Troponine T
TRO6	Troponine T
TROP	Troponine T
TYBC	TIJBC
UFBA	Bacterien
UFEM	Erytrocyten
UFER	Erytrocyten
UFLE	Leukocyten
URAA	Uraat
UREU	Ureum

Appendix K Excluded types of lab tests

Makey	Description
APR3	As.PR-3
A11	Monocyten
A15	Neutro.gran.
A21	Opmerking
A22	Opmerking
AALB	Albumine alv
ABIL	Bilirubine
ACAG	As.Card.IgG
ACAM	As.Card.IgM
ACE	ACE
AFP	Foetopr.(A1)
AHB	Hemoglobine
AKRI	Kristallen
ALDH	LD a.l.v.
ALEU	Leukocyten
ALSE	Albumine
AMPO	as.MPO
ANA	ANA
ANCF	ANCA (fluor)
ANCT	ANCA (titer)
APOE	ApoE genotyp
ASDN	AsDNA(Elisa)
ASPA	As.par.cel
ASTG	anti tTG
ATH	a-thalass.
BAS%	Basofielen %
BGMA	Materiaal
BGRC	Bloedgr.Rh.
BIDE	Irr.as.id.
BLKW	Bloedkweek
BRKT	Rh.KELL typ.
BRM	BR-MA
C125	CA 125
C3	C3
C4	C4
CA24	Calcium/24 U
CAU	Calcium U
CCP	anti-CCP
CEA	CEA
CO24	Cortisol/24U
CONC	Conclusie:
CONL	Conclusie:
CORT	Cortisol
CORT08	Cortisol 08u
COU	Cortisol U
DFRA#	Fragmentocyt
DIFO	Dif opm.
DIGO	Digoxine

Makey	Description
DIN2	Diff.indic.
DINF	Informatie
EIBJ	Eiwit kwant.
ENA	ENA screen
EO#	Eosinofiel #
EO%	Eosinofiel %
FA2M	FII mutatie
FA5M	FV mutatie
FA8	Factor VIII
FERR	Ferritine
FOLI	Foliumzuur
FT3	FT3
GADV	anti-GAD
GLA	Glucose afd.
GLHB	HbA1c
GLU	Glucose U
H129	Kop hemost.
H137	Trombo aant.
H139	Bldtijd Surg
H154	Factor VIII
H177	Ristocetine
H178	Collageen
H180	ADP
H181	Concl.hemost
H188	Arachidonzr.
H191	PFA EPI
HBA	HbA
HBA2	HbA2
HBCL	Conclusie:
HBO	Hb Opmerking
HI24	HIAA(5)/24 U
HOMC	Homocysteine
IGA	IgA
IMFU	Imm.fixatieU
INFA	ACS inform.
K24	Kalium/24 U
KDIU	Diurese
KI04	Info urine
KKUR	Kreatinine U
KUIT	Uitscheiding
LI01	Punctietijd
LI02	Centrifug.
LI04	Aspect (na)
LI05	Klin.gegev.
LI10	Lymfocyten
LI11	Monocyten
LI15	Neutro.gran.
LI21	Opmerking

Makey	Description
LI22	Kwalitatief
LUAC	LAC
LYM#	Lymfocyten #
LYM%	Lymfocyten %
MA24	mAlb/24uur
MALP	Parasitemie
MDRD	eGFR-MDRD
ME24	Metanef/24 U
MON#	Monocyten #
MON%	Monocyten %
NA24	Natrium/24 U
NEU#	Neutrofiel #
NEU%	Neutrofiel %
NO24	Normeta/24 U
OHBL	OxyHb
OPKC	Opm. KC
OPMC	Opm. chemie
OPMU	Opm. urine
PCR	Onderz. PCR
PHA	pH
PRC	Proteine C
PRS	Proteine S
PSAA	PSA
PTH	PTH
QALB	Album. ratio
RET#	Reticulocyt.
SPEO	M-prot. opm.
SPYL	Spijtliquor
SSLY	Slijm
STEE	Steen kwant
TE	Eiwit plasma
TEU	Eiwit(tot.)U
TRA	as.TSH rec.
TROC	Tromb. CITR.
TROD	Trombo.dif
TSH	TSH
TSHS	TSH (screen)
UFEP	Plav.epith.
UR24	Ureum/24 U
URU	Ureum U
VALP	Valproinez.
VB1	Vitamine B1
VB12	Vitamine B12
VB6	Vitamine B6
VO24	Volume 24 u
XCPE	C-peptide

Appendix L Coding of radiology tests

Test	Code
Antegrade pyelografie	5
Bekken/heupen	1
Bovenbeen links	1
Bovenbeen rechts	1
Buikoverzicht	1
Cervicale wervelkolom	1
Coloninloop	5
CT aangezicht	2
CT abdomen blanco	2
CT abdomen met contrast	2
CT bekken (bot)	2
CT cervicale wervelkolom	2
CT elleboog/o-arm links	2
CT enkel/calcaneus links	2
CT hals	2
CT heup/bovenbeen links	2
CT heup/bovenbeen rechts	2
CT knie/onderbeen links	2
CT knie/onderbeen rechts	2
CT lever (geen EZ-cat)	2
CT lumbale wervelkolom	2
CT nieren	2
CT nieren tot blaas (blanco)	2
CT pancreas	2
CT pols/hand links	2
CT schedel blanco	2
CT schedel met contrast	2
CT sinus/neusbijholten	2
CT thoracale wervelkolom	2
CT thorax met contrast	2
CT thorax via longpoli	2
CT thorax/abdomen	2
CT thorax/lever (geen EZ-cat)	2
CTA abdominale vaten	2
CTA aorta thor/abdominaal	2
CTA thorax	2
Doorl. bov. extr. rechts	9
Doorl. ond. extr. links	9
Doorl. ond. extr. rechts	9
Doorlichting abdomen	9
Doorlichting bov. extr. links	9
Doorlichting ERCP	9
Doorlichting ond. extr. beiderzijds	9
Echo nieren	3
Echo onderbuik	3

Tests	Code
Echo onderste extremiteit links	3
Echo nieren	3
Echo onderbuik	3
Echo onderste extremiteit links	3
Echo onderste extremiteit rechts	3
Echo testis	3
Echo thorax(wand)	3
Echogel.diagn.punctie bov. extr. rechts	3
Echogeleide diagn.punctie abdomen	3
Echogeleide diagn.punctie thorax	3
Echogeleide drainage abdomen	3
Echogeleide drainage galwegen	3
Elleboog links	1
Elleboog rechts	1
Enkel links	1
Enkel rechts	1
Hand links	1
Hand rechts	1
Heup beiderzijds	1
Heup links	1
Heup rechts	1
Humerus links	1
ia seldinger armvaten rechts	5
ia seldinger bekken/benen rechts	5
Knie beiderzijds	1
Knie links	1
LONGPERFUSIE SCINTIGRAFIE	5
Lumbale wervelkolom	1
MRA bekken/benen	4
MRI brughoek + schedel	4
MRI cervicale wervelkolom	4
MRI hals	4
MRI lumbale wervelkolom	4
MRI onderbeen rechts	4
MRI schedel	4
MRI schedel+hypofyse	4
MRI totale wervelkolom	4
MRI twk + lwk	4
MRI+MRA schedel	4
MRn Schedel + CWK	4
Oesophagus, slikfoto's	5
Onderbeen links	1
Onderbeen rechts	1
Opspuiten maagband	5
Orbita	1

Test	Code
Orbita corpus alienum tbv MRI	1
Pols links	1
Pols rechts	1
RENOGRAFIE (MAG3)	5
Sacrum/coccygis	1
Schouder links	1
Schouder rechts	1
Sinus	1
SKELETSCINTIGRAFIE TOTAAL	5
Sternum	1
Thoracale wervelkolom	1
Thorax	1
Urokinase been	5
Vinger(s) links	1
Voet links	1
Voet rechts	1
Voorvoet/tenen rechts	1
Zygoma	1

Appendix M Comparison before and during AAU

Mann-Whitney Test

Ranks

	code	N	Mean Rank	Sum of Ranks
LoS	Before	1287	1355,68	1744757,00
	During	1323	1256,69	1662598,00
	Total	2610		

Test Statistics[a]

	LoS
Mann-Whitney U	786772,000
Wilcoxon W	1662598,000
Z	-3,356
Asymp. Sig. (2-tailed)	,001

a. Grouping Variable: code

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		LoS
Most Extreme Differences	Absolute	,120
	Positive	,120
	Negative	-,007
Kolmogorov-Smirnov Z		3,055
Asymp. Sig. (2-tailed)		,000

a. Grouping Variable: code

Mann-Whitney Test

Ranks

	code	N	Mean Rank	Sum of Ranks
LoS	ACH_Before	353	390,61	137885,50
	ACH_During	372	336,80	125289,50
	Total	725		

Test Statistics[a]

	LoS
Mann-Whitney U	55911,500
Wilcoxon W	125289,500
Z	-3,459
Asymp. Sig. (2-tailed)	,001

a. Grouping Variable: code

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		LoS
Most Extreme Differences	Absolute	,181
	Positive	,181
	Negative	-,003
Kolmogorov-Smirnov Z		2,432
Asymp. Sig. (2-tailed)		,000

a. Grouping Variable: code

Mann-Whitney Test

Ranks

	code	N	Mean Rank	Sum of Ranks
LoS	INT_Before	350	359,49	125822,50
	INT_During	331	321,45	106398,50
	Total	681		

Test Statistics[a]

	LoS
Mann-Whitney U	51452,500
Wilcoxon W	106398,500
Z	-2,523
Asymp. Sig. (2-tailed)	,012

a. Grouping Variable: code

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		LoS
Most Extreme Differences	Absolute	,195
	Positive	,020
	Negative	-,195
Kolmogorov-Smirnov Z		2,543
Asymp. Sig. (2-tailed)		,000

a. Grouping Variable: code

Mann-Whitney Test

Ranks

	code	N	Mean Rank	Sum of Ranks
LoS	MDL_Before	137	138,42	18963,50
	MDL_During	130	129,34	16814,50
	Total	267		

Test Statistics[a]

	LoS
Mann-Whitney U	8299,500
Wilcoxon W	16814,500
Z	-,960
Asymp. Sig. (2-tailed)	,337

a. Grouping Variable: code

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		LoS
Most Extreme Differences	Absolute	,172
	Positive	,042
	Negative	-,172
Kolmogorov-Smirnov Z		1,403
Asymp. Sig. (2-tailed)		,039

a. Grouping Variable: code

Mann-Whitney Test

Ranks

	code	N	Mean Rank	Sum of Ranks
LoS	NEU_Before	151	147,68	22299,00
	NEU_During	144	148,34	21361,00
	Total	295		

Test Statistics[a]

	LoS
Mann-Whitney U	10823,000
Wilcoxon W	22299,000
Z	-,067
Asymp. Sig. (2-tailed)	,947

a. Grouping Variable: code

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		LoS
Most Extreme Differences	Absolute	,074
	Positive	,074
	Negative	-,051
Kolmogorov-Smirnov Z		,633
Asymp. Sig. (2-tailed)		,818

a. Grouping Variable: code

Mann-Whitney Test

Ranks

	code	N	Mean Rank	Sum of Ranks
LoS	PUL_Before	175	163,13	28548,00
	PUL_During	156	169,22	26398,00
	Total	331		

Test Statistics[a]

	LoS
Mann-Whitney U	13148,000
Wilcoxon W	28548,000
Z	-,578
Asymp. Sig. (2-tailed)	,563

a. Grouping Variable: code

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		LoS
Most Extreme Differences	Absolute	,085
	Positive	,085
	Negative	-,045
Kolmogorov-Smirnov Z		,770
Asymp. Sig. (2-tailed)		,593

a. Grouping Variable: code

Mann-Whitney Test

Ranks

	code	N	Mean Rank	Sum of Ranks
LoS	URO_Before	80	89,29	7143,50
	URO_During	93	85,03	7907,50
	Total	173		

Test Statistics[a]

	LoS
Mann-Whitney U	3536,500
Wilcoxon W	7907,500
Z	-,559
Asymp. Sig. (2-tailed)	,576

a. Grouping Variable: code

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		LoS
Most Extreme Differences	Absolute	,114
	Positive	,114
	Negative	-,046
Kolmogorov-Smirnov Z		,750
Asymp. Sig. (2-tailed)		,627

a. Grouping Variable: code

Appendix N Normality tests for inflow per day of the week

The normality has been tested in three different ways, first, the kurtosis and skewness are considered, second, normality plots are assessed, and finally, the normality is tested with a modification of the Kolmogorov-Smirnov test and the Shapiro-Wilk test (Hair et al., 2006). These three ways are chosen because a limited number of observations, according to Hair et al. (2006) fewer than 30, makes statistical tests quite sensitive to significant departures from normality. By not only depending on the statistical tests, but also on the normality plots, the chances of rejecting samples from being normally distributed when they indeed are normally distributed (Type I error, Montgomery & Runger (2003)) are hereby limited.

The skewness and kurtosis values are checked to see if the distribution is non-normal in terms of these characteristics. So with these tests it cannot be proven that the distribution follows a normal distribution; it can only be proven if it has non-normal characteristics (Hair et al., 2006). The skewness checks if the balance corresponds to that of the normal distribution, positive values indicate a shift to the left, negative values indicate a shift to the right. The kurtosis shows if the distribution is more peaked or flat compared to the normal distribution, positive values point to a peaked distribution, whereas negative values point to a flattened distribution. The skewness and kurtosis statistic values, just as several more general statistic values can be found in below.

The skewness and kurtosis have boundary values; within these values it cannot be statistically proven that the distributions are non-normal. The boundary values are dependent on the number of observations. Since the number of observations are the same for all weekdays, there are 13 complete weeks of data, the boundary values are the same for each day. They are +/-0.616 for the skewness and +/-1.191 for the kurtosis. The values in below indicate two non-normality values: for the number of admissions on Tuesday the Kurtosis value shows a non-normal value, -1.191, and for Thursday the Skewness value is too large, 0.990. This indicates that the number of admissions on Tuesday and Thursday could be non-normal. But before this conclusion is drawn lets continue and look at the normality plots in below.

For all days a normality plot is made, when the observations lie on or near the indicated line, the distributions follows a normal distribution. The plots of Tuesday and Thursday indicate that several observations do deviate from the expected normal line. The Tuesday plot could indicate a non-peaked or uniform distribution (Hair et al. 2006), but the last testing method should be reviewed if there is enough evidence for a non-normal distribution. All other days seem to follow the normal distribution.

The table at the end of this appendix shows the values for the Kolmogorov-Smirnov test and for the Shapiro-Wilk test. The only distribution which differs significantly from a normal distribution according to the Kolmogorow-Smirnov test is Thursday ($p<0.05$). The Shapiro-Wilk test, however, did not reveal any significant results for any of the days.

When all the tests are taking into account, the skewness and kurtosis, the normal probability plot and the specific statistical tests, there is enough evidence to suspect that the number of admissions on a Thursday is non-normal distributed. However, the number of observations are limited and there is no reason to suggest why the distribution of number of admissions on a Thursday are different from any other day. In the remainder of the report it is therefore assumed that also the number of admissions on a Thursday comes from a normal distribution.

Descriptives

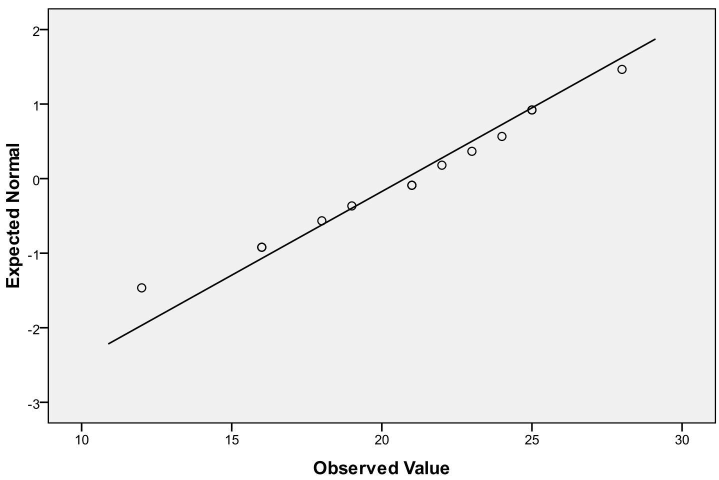
			Statistic	Std. Error
Monday	Mean		20,7692	1,23597
	95% Confidence Interval for Mean	Lower Bound	18,0763	
		Upper Bound	23,4622	
	5% Trimmed Mean		20,8547	
	Median		21,0000	

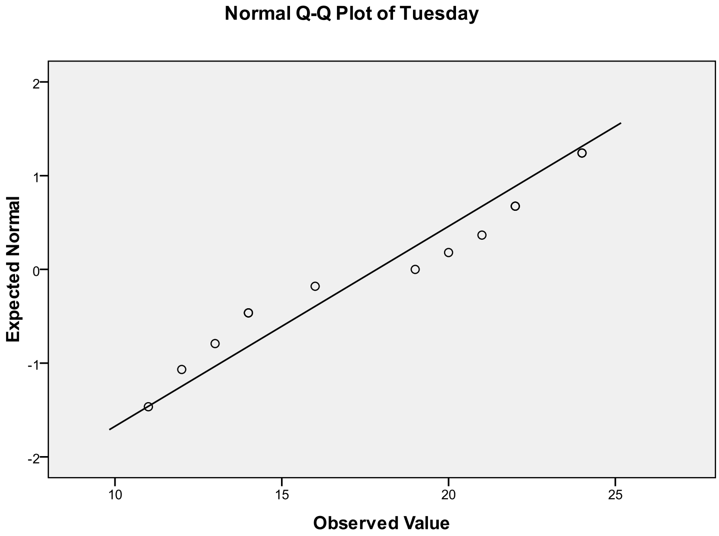
	Variance		19,859	
	Std. Deviation		4,45634	
	Minimum		12,00	
	Maximum		28,00	
	Range		16,00	
	Interquartile Range		7,50	
	Skewness		-,380	,616
	Kurtosis		-,247	1,191
Tuesday	Mean		17,8462	1,30013
	95% Confidence Interval for Mean	Lower Bound	15,0134	
		Upper Bound	20,6789	
	5% Trimmed Mean		17,8846	
	Median		19,0000	
	Variance		21,974	
	Std. Deviation		4,68768	
	Minimum		11,00	
	Maximum		24,00	
	Range		13,00	
	Interquartile Range		8,50	
	Skewness		-,098	,616
	Kurtosis		-1,657	1,191
Wednesday	Mean		19,6923	,84265
	95% Confidence Interval for Mean	Lower Bound	17,8563	
		Upper Bound	21,5283	
	5% Trimmed Mean		19,7137	
	Median		20,0000	
	Variance		9,231	
	Std. Deviation		3,03822	
	Minimum		14,00	
	Maximum		25,00	
	Range		11,00	
	Interquartile Range		4,00	
	Skewness		-,054	,616
	Kurtosis		,063	1,191

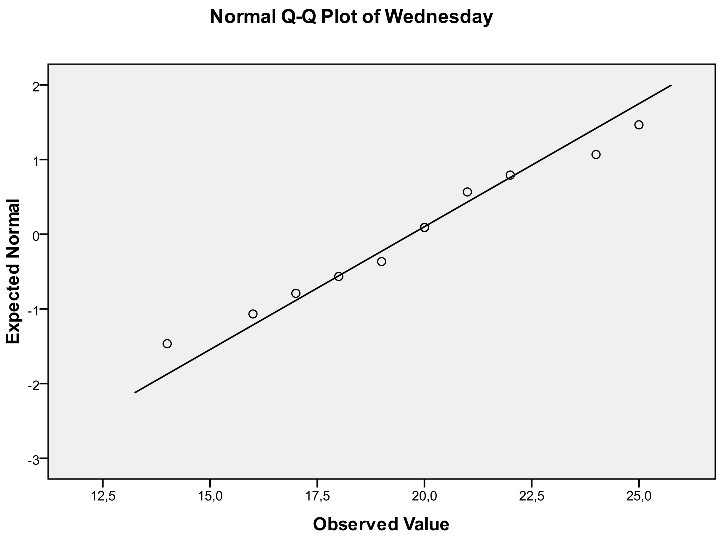
Thursday	Mean	17,6154	1,33752
	95% Confidence Interval for Mean Lower Bound	14,7012	
	Upper Bound	20,5296	
	5% Trimmed Mean	17,3504	
	Median	17,0000	
	Variance	23,256	
	Std. Deviation	4,82249	
	Minimum	12,00	
	Maximum	28,00	
	Range	16,00	
	Interquartile Range	6,00	
	Skewness	,990	,616
	Kurtosis	,528	1,191
Friday	Mean	19,2308	1,25654
	95% Confidence Interval for Mean Lower Bound	16,4930	
	Upper Bound	21,9685	
	5% Trimmed Mean	19,1453	
	Median	20,0000	
	Variance	20,526	
	Std. Deviation	4,53052	
	Minimum	12,00	
	Maximum	28,00	
	Range	16,00	
	Interquartile Range	7,50	
	Skewness	,242	,616
	Kurtosis	-,485	1,191
Saturday	Mean	11,8462	,84615
	95% Confidence Interval for Mean Lower Bound	10,0025	
	Upper Bound	13,6898	
	5% Trimmed Mean	11,8291	
	Median	11,0000	
	Variance	9,308	
	Std. Deviation	3,05085	
	Minimum	6,00	

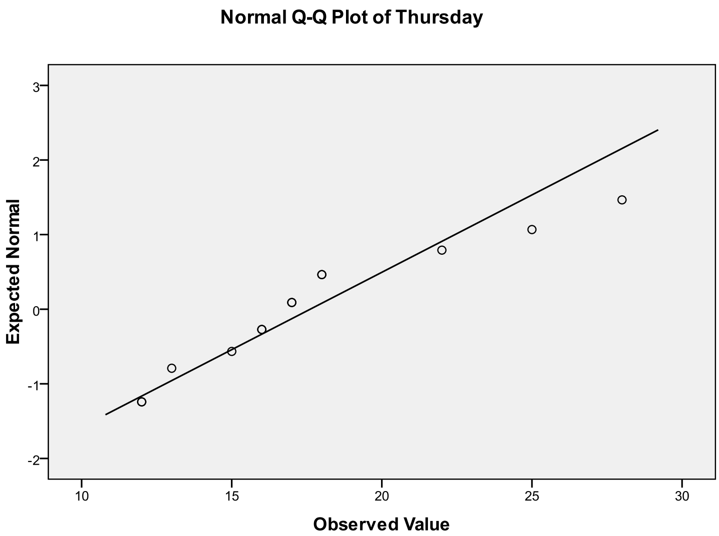
	Maximum	18,00	
	Range	12,00	
	Interquartile Range	3,50	
	Skewness	,318	,616
	Kurtosis	,804	1,191
Sunday	Mean	14,0000	,93370
	95% Confidence Interval for Mean Lower Bound	11,9656	
	Upper Bound	16,0344	
	5% Trimmed Mean	14,1111	
	Median	15,0000	
	Variance	11,333	
	Std. Deviation	3,36650	
	Minimum	7,00	
	Maximum	19,00	
	Range	12,00	
	Interquartile Range	5,00	
	Skewness	-,558	,616
	Kurtosis	,083	1,191

Normal Q-Q Plot of Monday

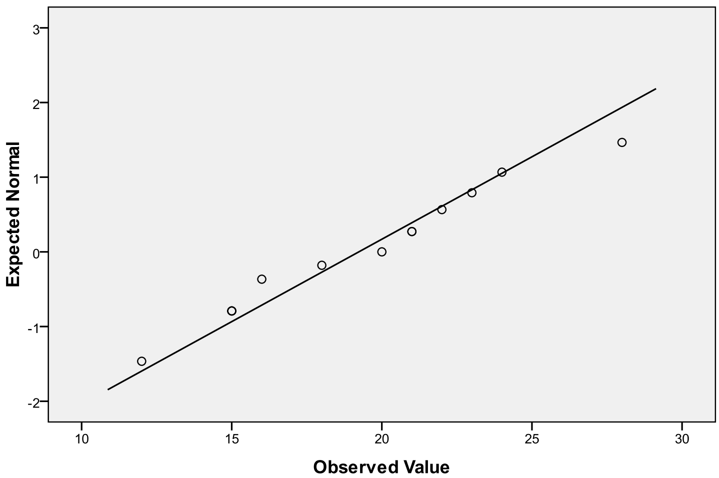



Normal Q-Q Plot of Tuesday
Expected Normal
Observed Value
2
1
0
-1
-2
10
15
20
25

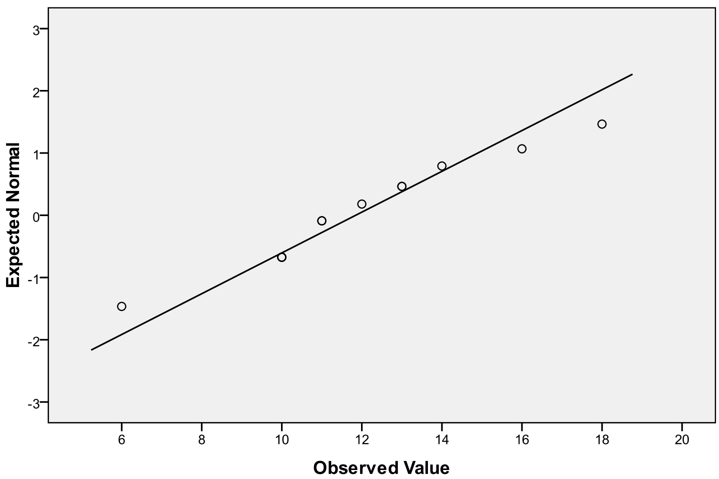

Normal Q-Q Plot of Wednesday
Expected Normal
Observed Value
2
1
0
-1
-2
-3
12,5
15,0
17,5
20,0
22,5
25,0


Normal Q-Q Plot of Thursday
Expected Normal
Observed Value
3
2
1
0
-1
-2
10
15
20
25
30

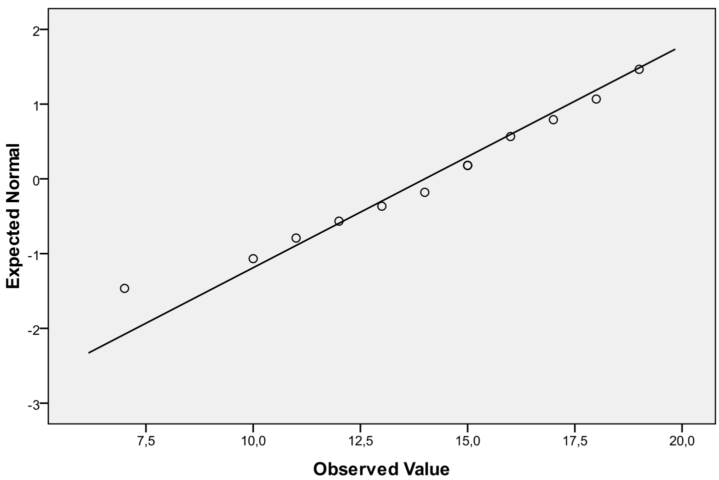
Normal Q-Q Plot of Friday



Normal Q-Q Plot of Saturday



Normal Q-Q Plot of Sunday



Tests of Normality

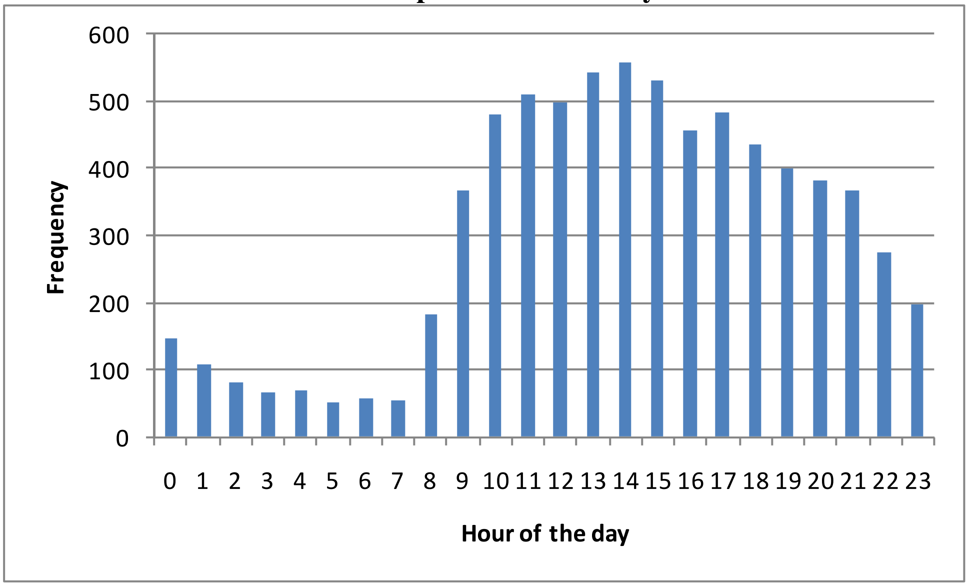
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Monday	,136	13	,200*	,976	13	,957
Tuesday	,179	13	,200*	,909	13	,176
Wednesday	,156	13	,200*	,973	13	,928
Thursday	,237	13	,043	,900	13	,135
Friday	,147	13	,200*	,963	13	,802
Saturday	,196	13	,185	,947	13	,557
Sunday	,155	13	,200*	,971	13	,910

a. Lilliefors Significance Correction

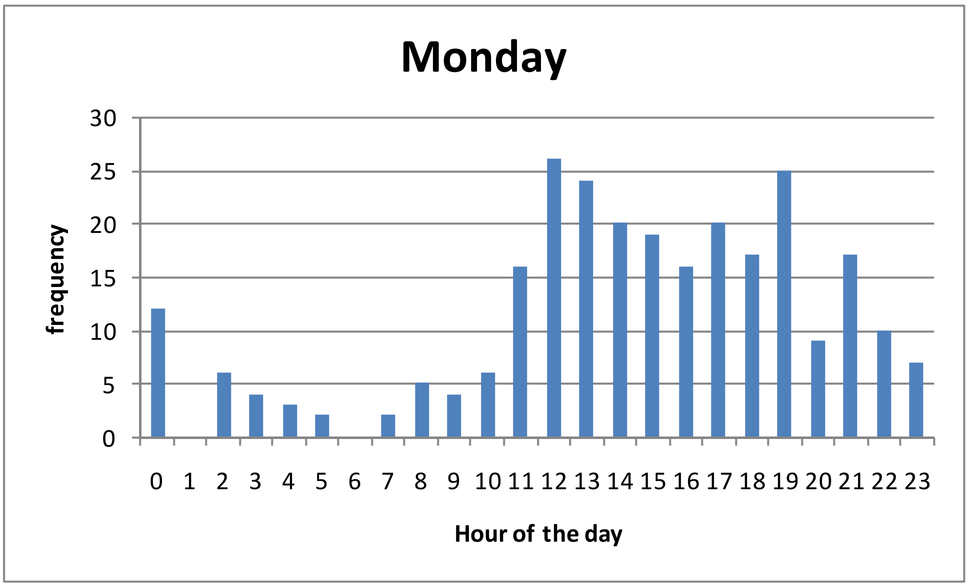
*. This is a lower bound of the true significance.

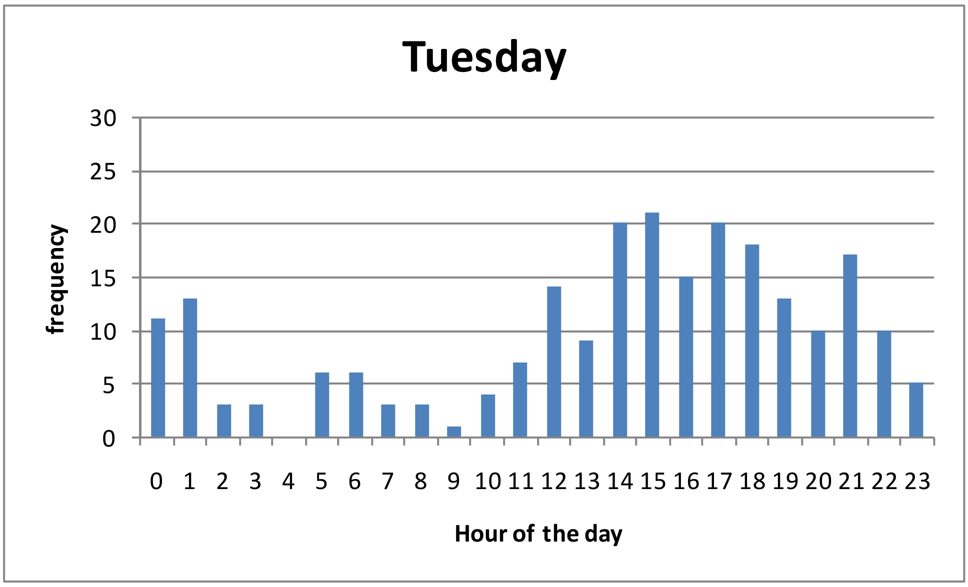
Appendix O Inflow patterns

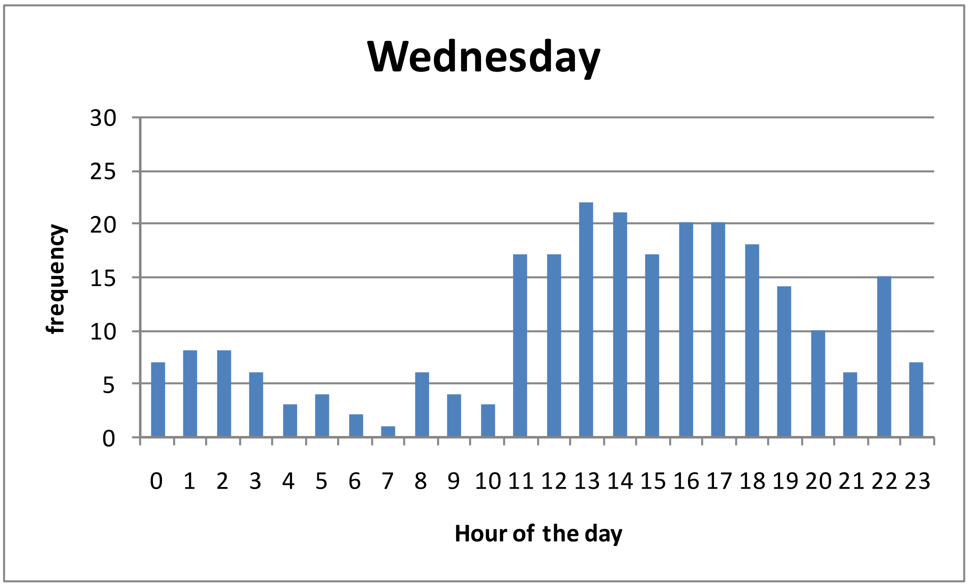
Number of admissions at the ED per hour of the day

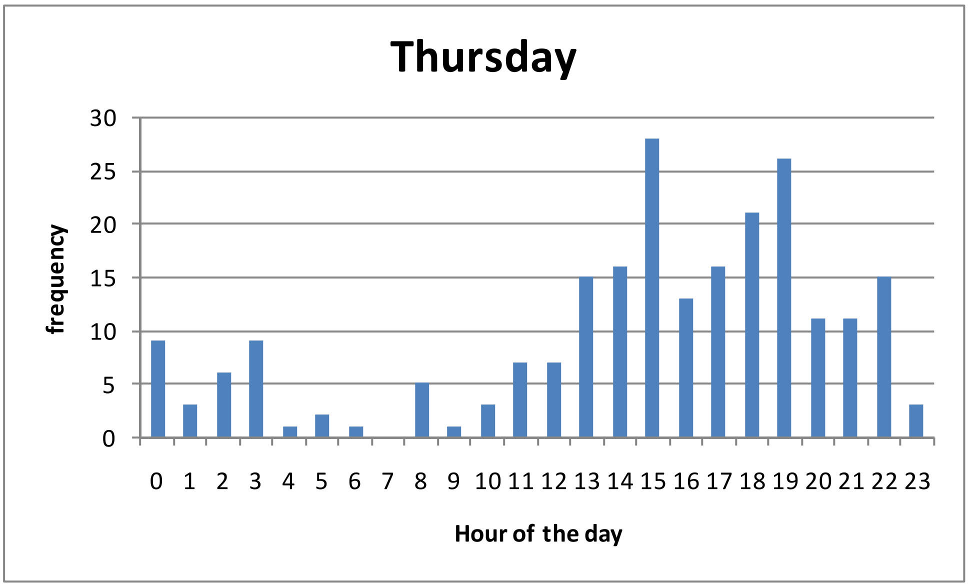


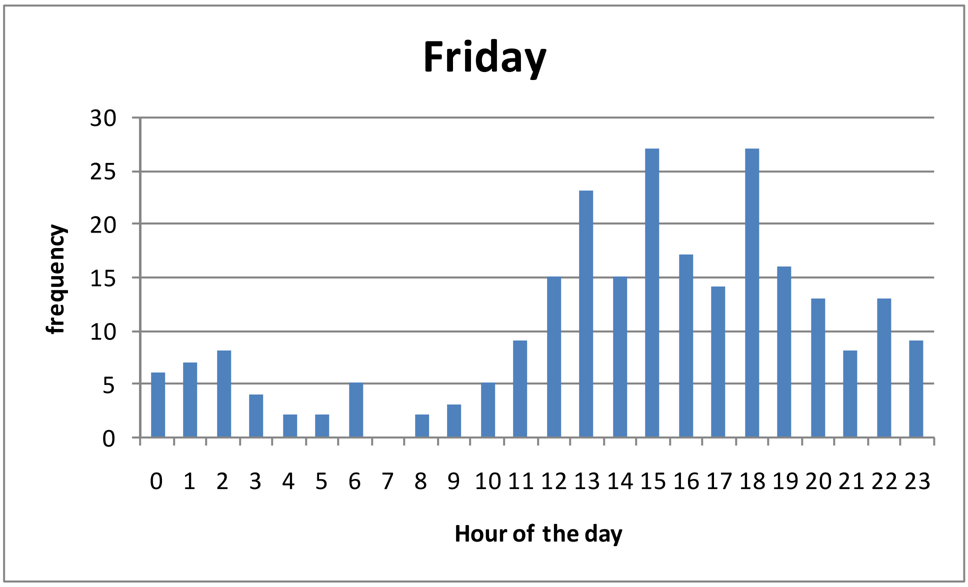
Number of admissions per hour of the day for all days of the week

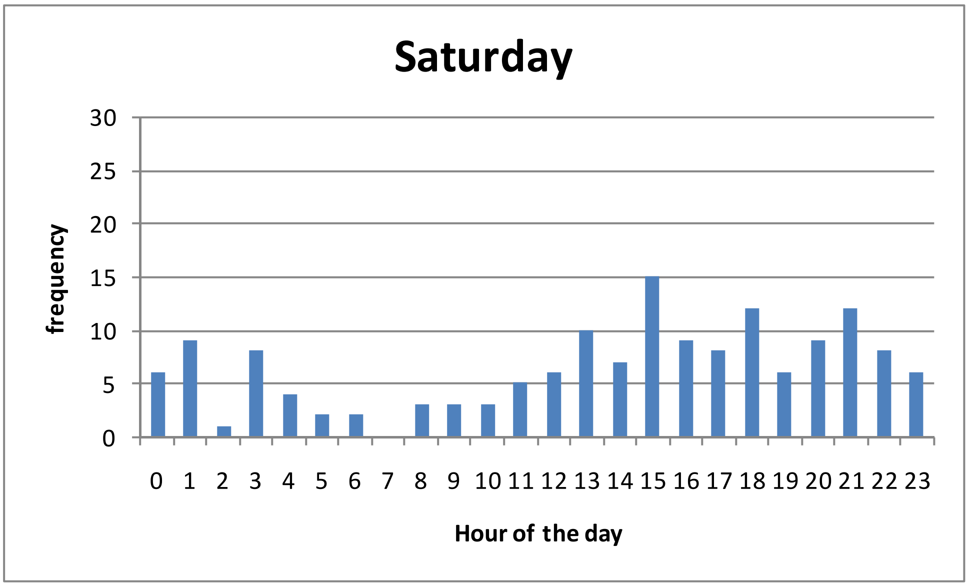


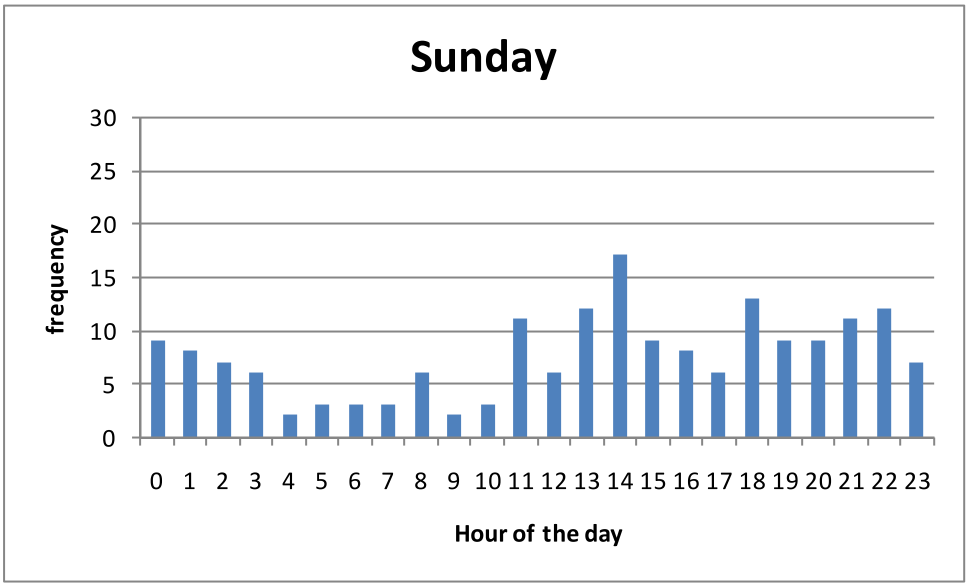

Tuesday
frequency
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of the day


Wednesday
frequency
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of the day


Thursday
frequency
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of the day


Friday
frequency
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of the day


Saturday
frequency
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of the day

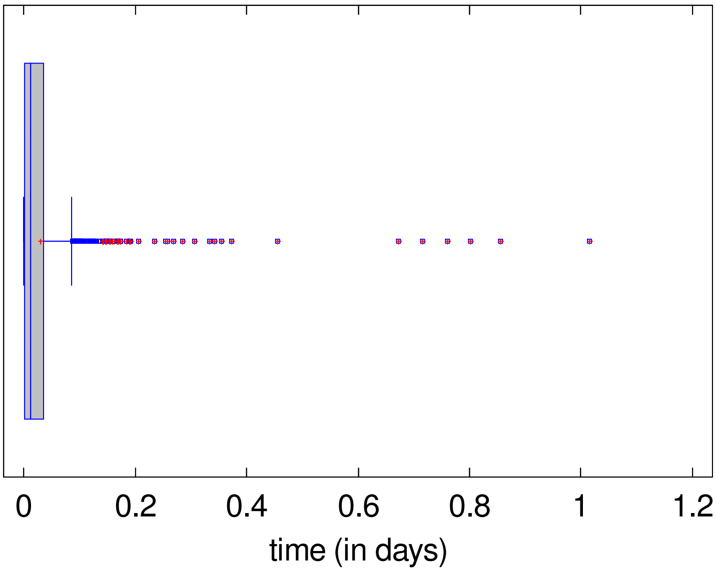

Sunday
frequency
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of the day

Appendix P AAU access time

Access time with outliers (in days)

Summary Statistics for Acces_time

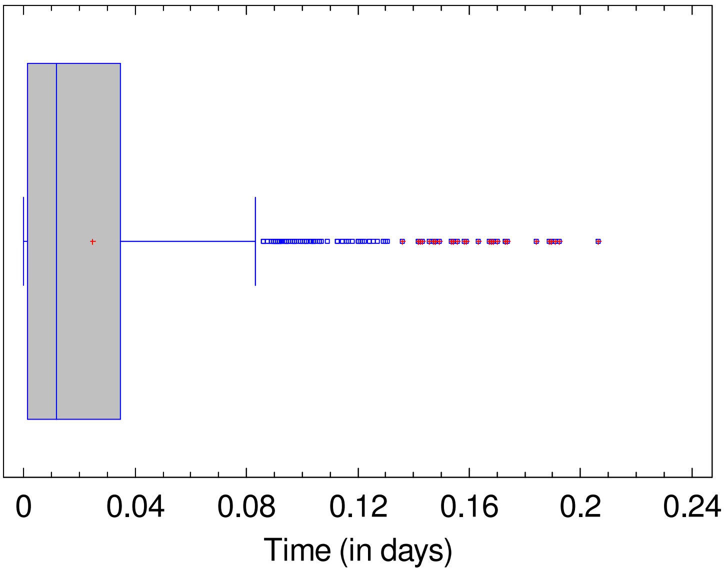
Count	1573
Average	0.0296227
Standard deviation	0.0638142
Coeff. of variation	215.423%
Minimum	0.0
Maximum	1.01597
Range	1.01597
Stnd. skewness	133.594
Stnd. kurtosis	773.706



Access time without outliers (in days)

Summary Statistics for Acces_time_filtered

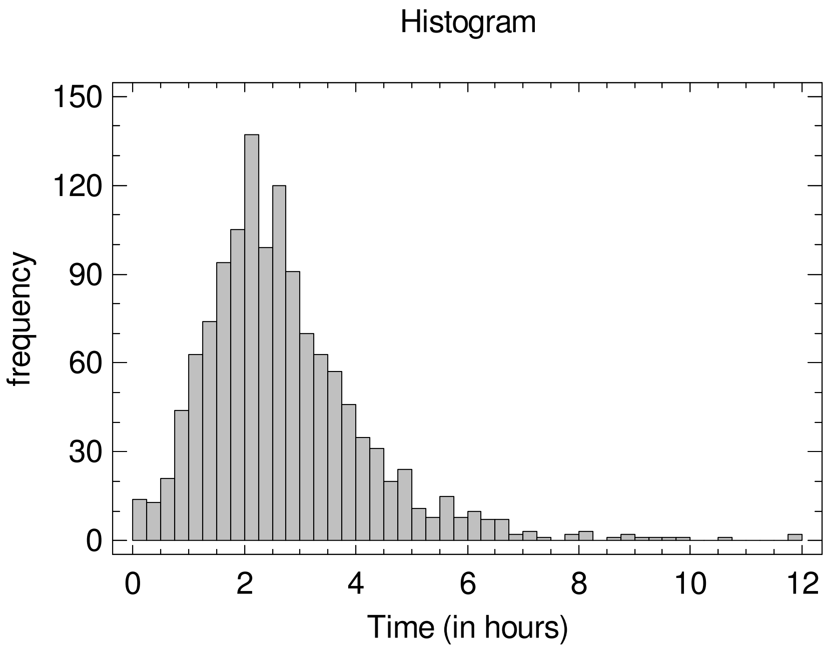
Count	1556
Average	0.0246189
Standard deviation	0.0335616
Coeff. of variation	136.325%
Minimum	0.0
Maximum	0.20625
Range	0.20625
Stnd. skewness	36.4489
Stnd. kurtosis	47.9693



Appendix Q ED-AAU access time

Summary Statistics for ED_AAU_access_time*24

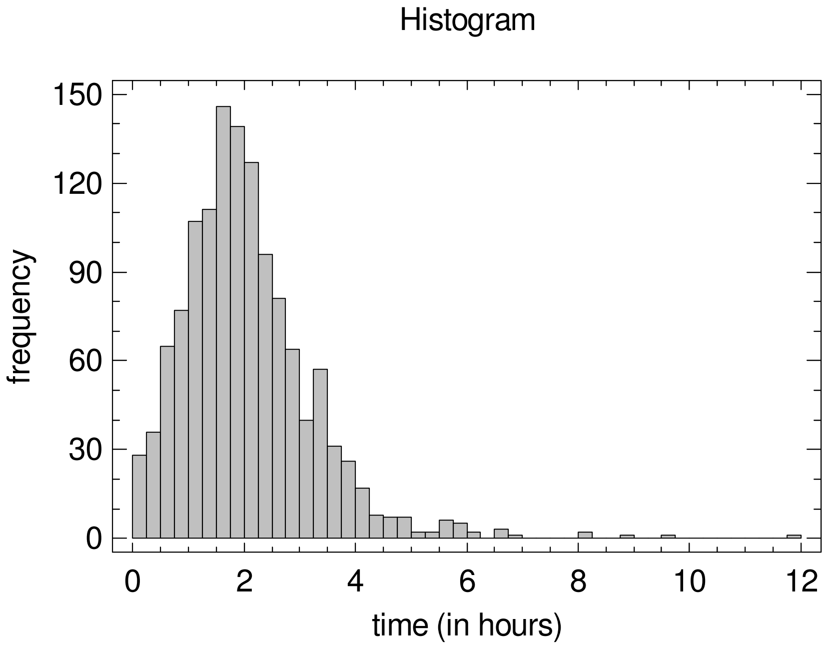
Count	1308
Average	2.72054
Standard deviation	1.4781
Coeff. of variation	54.3312%
Minimum	0.0166667
Maximum	11.8833
Range	11.8667
Stnd. skewness	22.909
Stnd. kurtosis	34.6774

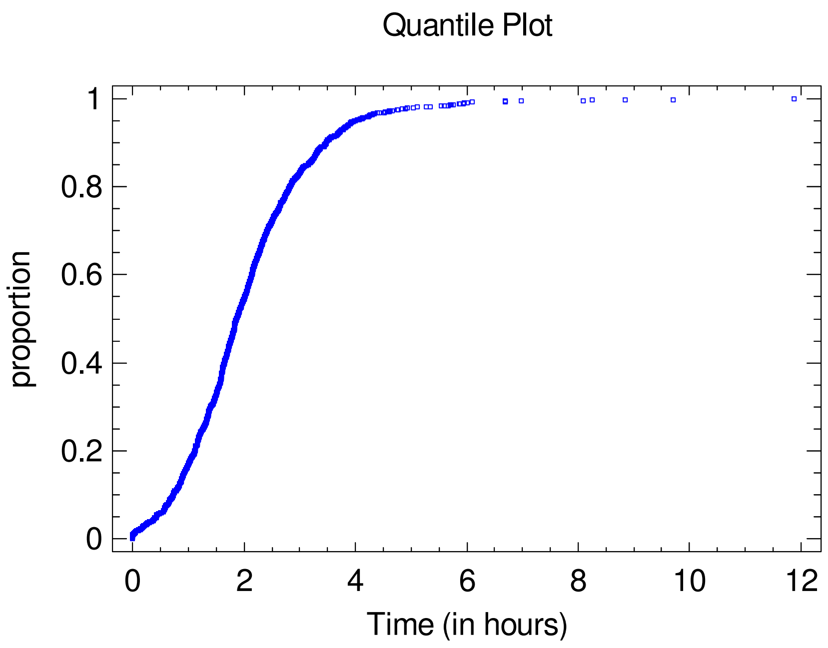


Appendix R ED-AAU access time minus AAU access time

Summary Statistics for ES__AS_AN_*24

Count	1308
Average	2.03723
Standard deviation	1.19332
Coeff. of variation	58.5755%
Minimum	0.0
Maximum	11.8833
Range	11.8833
Stnd. skewness	24.0656
Stnd. kurtosis	51.6498





Appendix S Bed Utilization statistics

Descriptives

dayname			Statistic	Std. Error
1_Monday		Mean	.63338164	.029068092
	95% Confidence Interval for Mean	Lower Bound	.56940321	
		Upper Bound	.69736008	
		5% Trimmed Mean	.62985899	
		Median	.60476811	
		Variance	,010	
		Std. Deviation	.100694823	
		Minimum	.511508	
		Maximum	.818663	
		Range	.307155	
		Interquartile Range	.135979	
		Skewness	,835	,637
		Kurtosis	-,290	1,232
2_Tuesda		Mean	.73046350	.028409096
	95% Confidence Interval for Mean	Lower Bound	.66856540	
		Upper Bound	.79236161	
		5% Trimmed Mean	.73561511	
		Median	.75476191	
		Variance	,010	
		Std. Deviation	.102430451	
		Minimum	.513120	
		Maximum	.855078	
		Range	.341958	
		Interquartile Range	.147724	
		Skewness	-,930	,616
		Kurtosis	,170	1,191
3_Wednes		Mean	.74610806	.024497610
	95% Confidence Interval for Mean	Lower Bound	.69273235	
		Upper Bound	.79948377	

			Statistic	Std. Error
		5% Trimmed Mean	.75115264	
		Median	.76468254	
		Variance	,008	
		Std. Deviation	.088327389	
		Minimum	.557540	
		Maximum	.843874	
		Range	.286334	
		Interquartile Range	.124816	
		Skewness	-1,093	,616
		Kurtosis	,292	1,191
4_Thursd		Mean	.77655058	.019577549
	95% Confidence Interval for Mean	Lower Bound	.73389476	
		Upper Bound	.81920639	
		5% Trimmed Mean	.77503635	
		Median	.77108135	
		Variance	,005	
		Std. Deviation	.070587858	
		Minimum	.679439	
		Maximum	.900918	
		Range	.221478	
		Interquartile Range	.105949	
		Skewness	,546	,616
		Kurtosis	-,617	1,191
5_Friday		Mean	.72478680	.017298090
	95% Confidence Interval for Mean	Lower Bound	.68709750	
		Upper Bound	.76247610	
		5% Trimmed Mean	.72649371	
		Median	.72447917	
		Variance	,004	
		Std. Deviation	.062369150	
		Minimum	.610913	
		Maximum	.807937	
		Range	.197024	

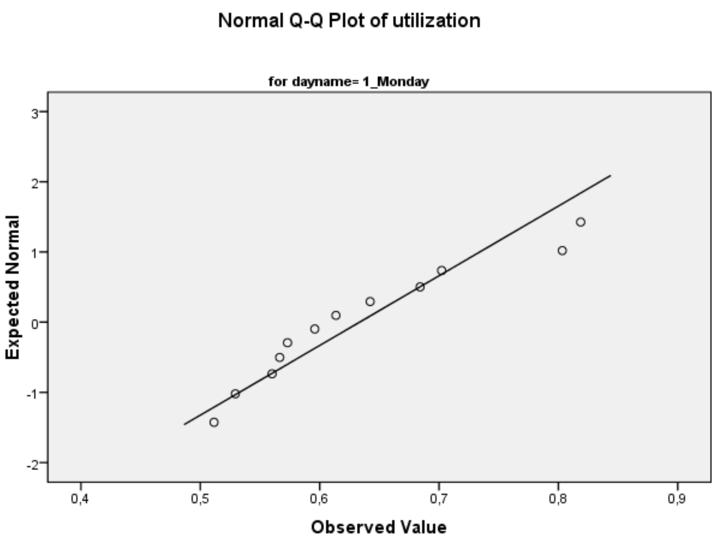
		Interquartile Range	.109764	
		Skewness	-,349	,616
		Kurtosis	-,924	1,191
6_Saturd		Mean	.60589705	.020634875
	95% Confidence Interval for Mean	Lower Bound	.56093752	
		Upper Bound	.65085658	
		5% Trimmed Mean	.60491262	
		Median	.61614583	
		Variance	,006	
		Std. Deviation	.074400099	
		Minimum	.491406	
		Maximum	.738108	
		Range	.246701	
		Interquartile Range	.117093	
		Skewness	-,022	,616
		Kurtosis	-,620	1,191
7_Sunday		Mean	.53090373	.034843698
	95% Confidence Interval for Mean	Lower Bound	.45498583	
		Upper Bound	.60682163	
		5% Trimmed Mean	.52862760	
		Median	.50609809	
		Variance	,016	
		Std. Deviation	.125630742	
		Minimum	.352951	
		Maximum	.749826	
		Range	.396875	
		Interquartile Range	.223661	
		Skewness	,380	,616
		Kurtosis	-,854	1,191

Tests of Normality

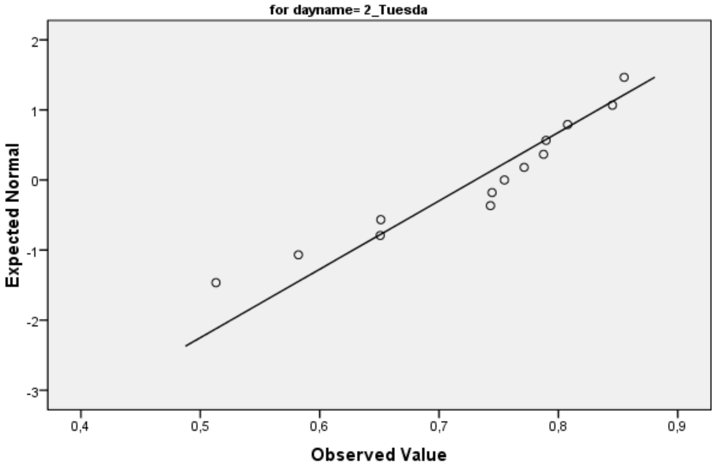
	dayname	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
utilization	1_Monday	,161	12	,200*	,908	12	,200
	2_Tuesda	,241	13	,037	,910	13	,185
	3_Wednes	,238	13	,043	,872	13	,056
	4_Thursd	,145	13	,200*	,943	13	,502
	5_Friday	,116	13	,200*	,954	13	,667
	6_Saturd	,107	13	,200*	,971	13	,907
	7_Sunday	,155	13	,200*	,951	13	,618

a. Lilliefors Significance Correction

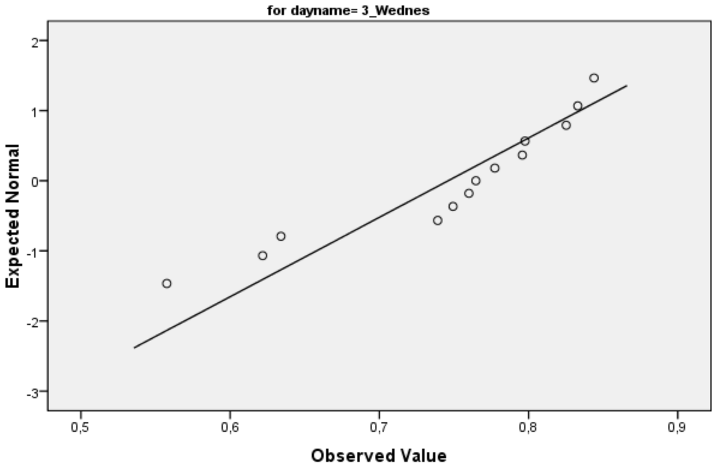
*. This is a lower bound of the true significance.



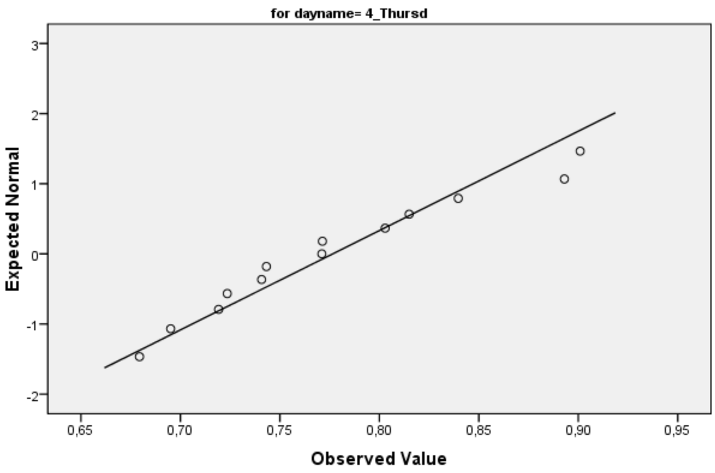
Normal Q-Q Plot of utilization



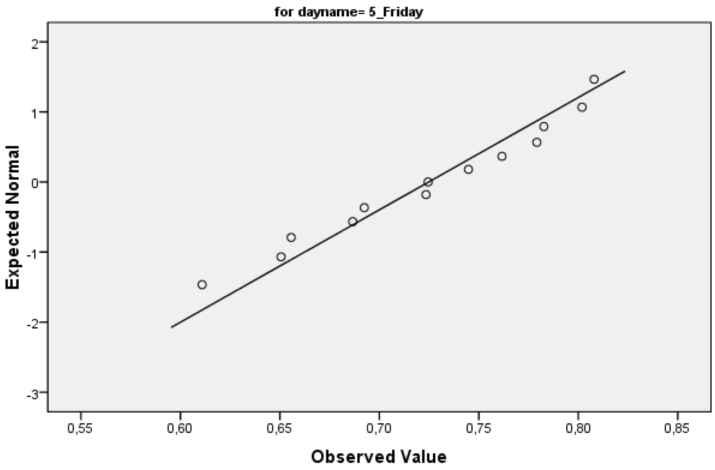
Normal Q-Q Plot of utilization



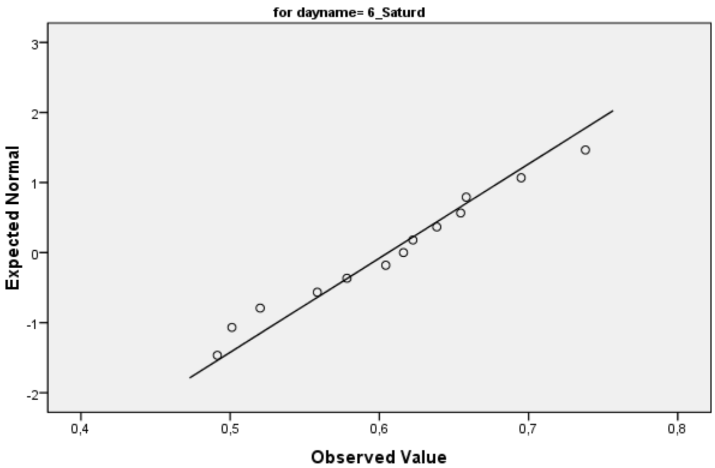
Normal Q-Q Plot of utilization



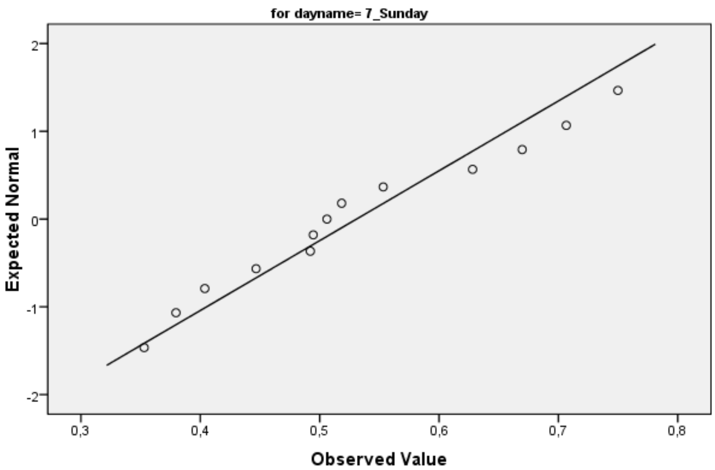
Normal Q-Q Plot of utilization



Normal Q-Q Plot of utilization



Normal Q-Q Plot of utilization



Mann-Whitney Test

Ranks

	daycode	N	Mean Rank	Sum of Ranks
utilization	Tuesday	13	17,92	233,00
	Saturday	13	9,08	118,00
	Total	26		

Test Statistics[b]

	utilization
Mann-Whitney U	27,000
Wilcoxon W	118,000
Z	-2,949
Asymp. Sig. (2-tailed)	,003
Exact Sig. [2*(1-tailed Sig.)]	,002[a]

a. Not corrected for ties.

b. Grouping Variable: daycode

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		utilization
Most Extreme Differences	Absolute	,692
	Positive	,000
	Negative	-,692
	Kolmogorov-Smirnov Z	1,765
	Asymp. Sig. (2-tailed)	,004

a. Grouping Variable: daycode

Mann-Whitney Test

Ranks

	daycode	N	Mean Rank	Sum of Ranks
utilization	Monday	12	9,75	117,00
	Tuesday	13	16,00	208,00
	Total	25		

Test Statistics[b]

	utilization
Mann-Whitney U	39,000
Wilcoxon W	117,000
Z	-2,121
Asymp. Sig. (2-tailed)	,034
Exact Sig. [2*(1-tailed Sig.)]	,035[a]

a. Not corrected for ties.

b. Grouping Variable: daycode

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		utilization
Most Extreme Differences	Absolute	,526
	Positive	,000
	Negative	-,526
	Kolmogorov-Smirnov Z	1,313
	Asymp. Sig. (2-tailed)	,064

a. Grouping Variable: daycode

Mann-Whitney Test

Ranks

	daycode	N	Mean Rank	Sum of Ranks
utilization	Tuesday	13	18,62	242,00
	Sunday	13	8,38	109,00
	Total	26		

Test Statistics[b]

	utilization
Mann-Whitney U	18,000
Wilcoxon W	109,000
Z	-3,410
Asymp. Sig. (2-tailed)	,001
Exact Sig. [2*(1-tailed Sig.)]	,000[a]

a. Not corrected for ties.

b. Grouping Variable: daycode

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		utilization
Most Extreme Differences	Absolute	,615
	Positive	,000
	Negative	-,615
	Kolmogorov-Smirnov Z	1,569
	Asymp. Sig. (2-tailed)	,015

a. Grouping Variable: daycode

Mann-Whitney Test

Ranks

	daycode	N	Mean Rank	Sum of Ranks
utilization	Monday	12	9,33	112,00
	Wednesday	13	16,38	213,00
	Total	25		

Test Statistics[b]

	utilization
Mann-Whitney U	34,000
Wilcoxon W	112,000
Z	-2,393
Asymp. Sig. (2-tailed)	,017
Exact Sig. [2*(1-tailed Sig.)]	,016[a]

a. Not corrected for ties.

b. Grouping Variable: daycode

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		utilization
Most Extreme Differences	Absolute	,603
	Positive	,000
	Negative	-,603
	Kolmogorov-Smirnov Z	1,505
	Asymp. Sig. (2-tailed)	,022

a. Grouping Variable: daycode

Mann-Whitney Test

Ranks

	daycode	N	Mean Rank	Sum of Ranks
utilization	Wednesday	13	18,38	239,00
	Saturday	13	8,62	112,00
	Total	26		

Test Statistics[b]

	utilization
Mann-Whitney U	21,000
Wilcoxon W	112,000
Z	-3,256
Asymp. Sig. (2-tailed)	,001
Exact Sig. [2*(1-tailed Sig.)]	,001[a]

a. Not corrected for ties.

b. Grouping Variable: daycode

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		utilization
Most Extreme Differences	Absolute	,769
	Positive	,000
	Negative	-,769
	Kolmogorov-Smirnov Z	1,961
	Asymp. Sig. (2-tailed)	,001

a. Grouping Variable: daycode

Mann-Whitney Test

Ranks

	daycode	N	Mean Rank	Sum of Ranks
utilization	Wednesday	13	19,00	247,00
	Sunday	13	8,00	104,00
	Total	26		

Test Statistics[b]

	utilization
Mann-Whitney U	13,000
Wilcoxon W	104,000
Z	-3,667
Asymp. Sig. (2-tailed)	,000
Exact Sig. [2*(1-tailed Sig.)]	,000[a]

a. Not corrected for ties.

b. Grouping Variable: daycode

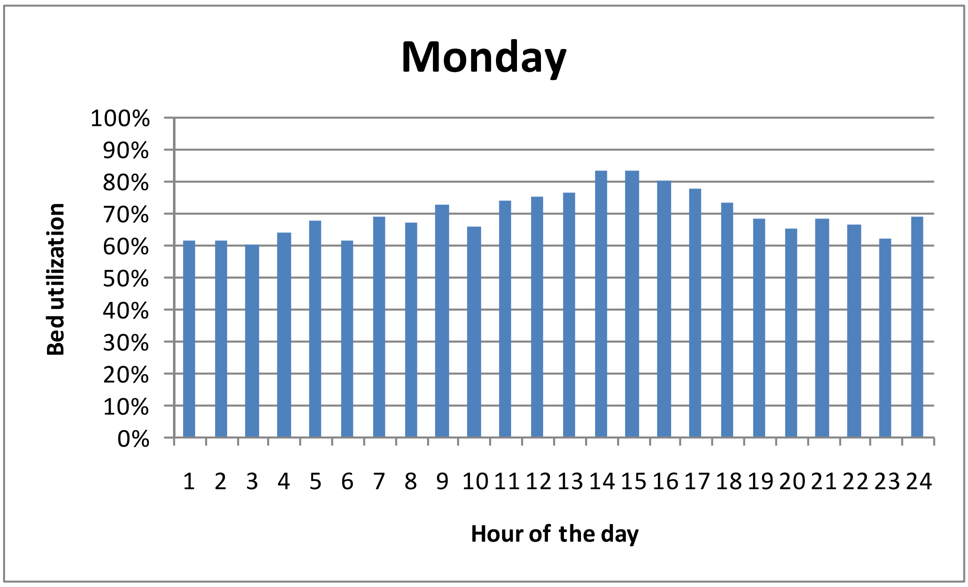
Two-Sample Kolmogorov-Smirnov Test

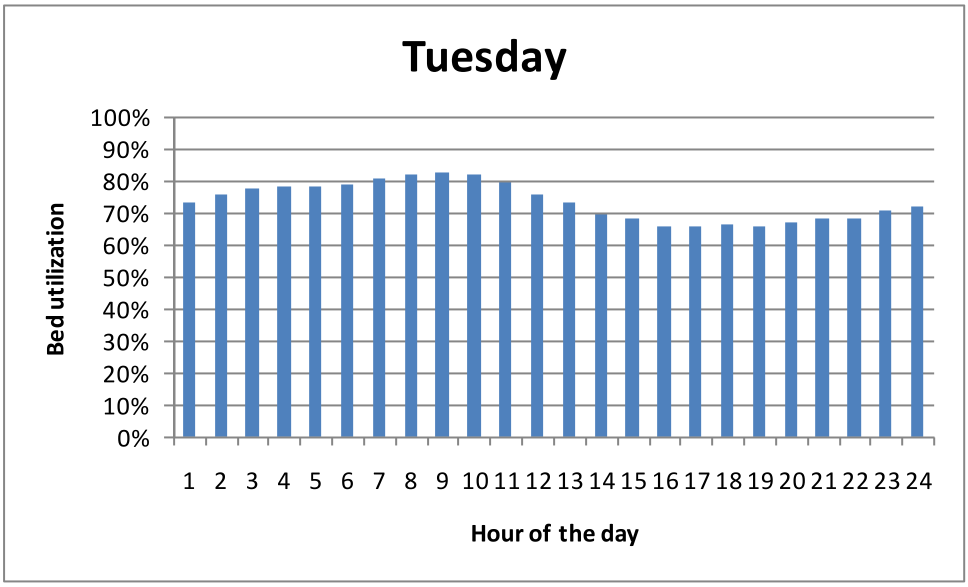
Test Statistics[a]

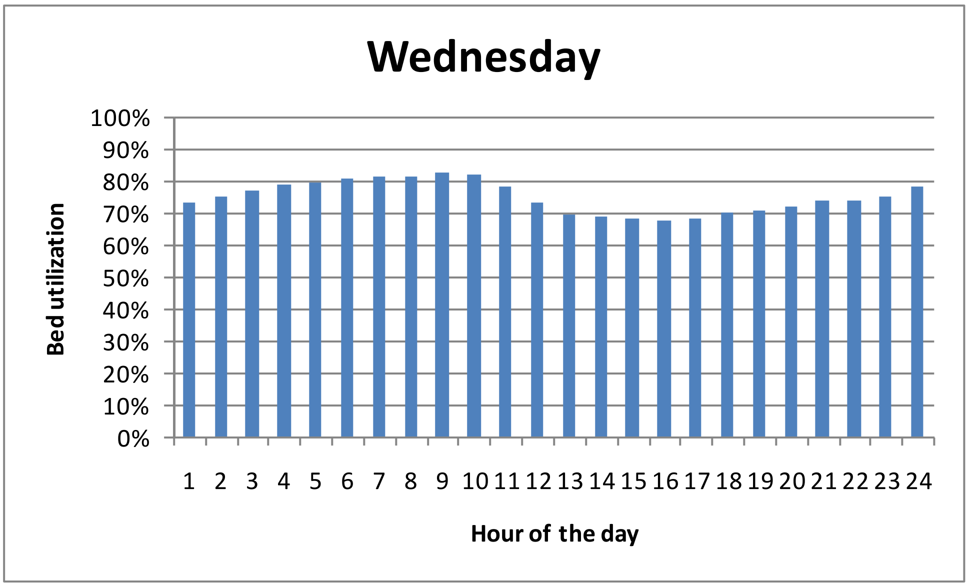
		utilization
Most Extreme Differences	Absolute	,692
	Positive	,000
	Negative	-,692
	Kolmogorov-Smirnov Z	1,765
	Asymp. Sig. (2-tailed)	,004

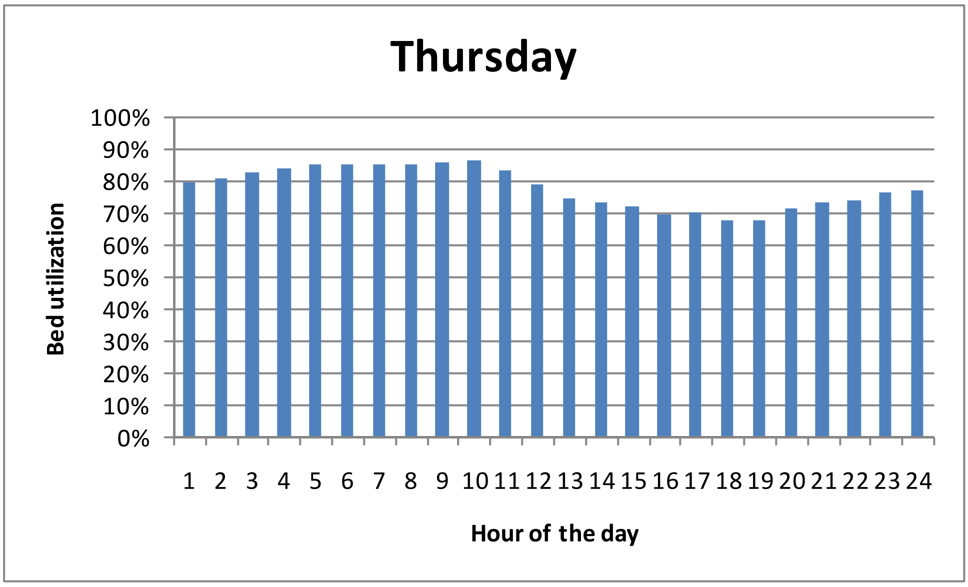
a. Grouping Variable: daycode

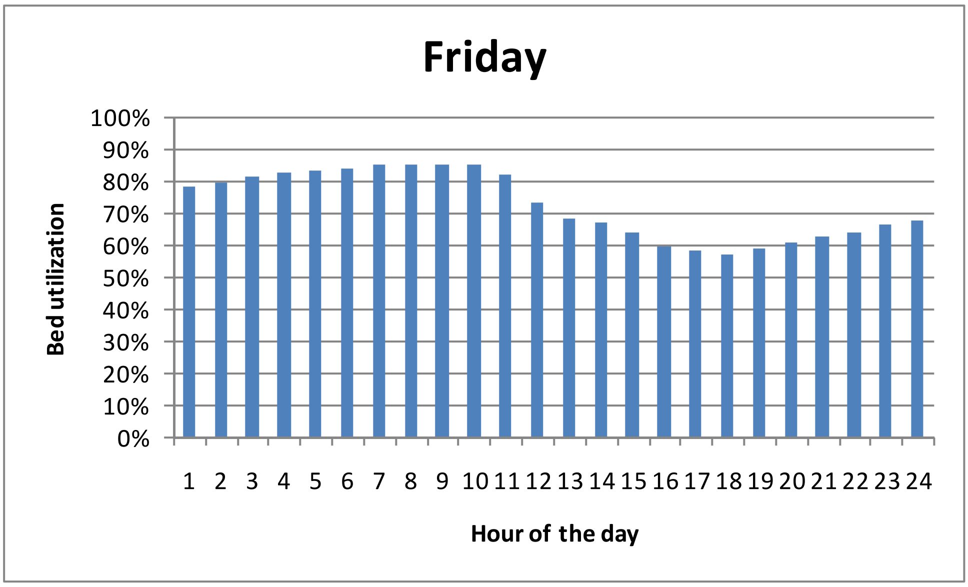
Appendix T Average bed utilization levels per hour, per day of the week

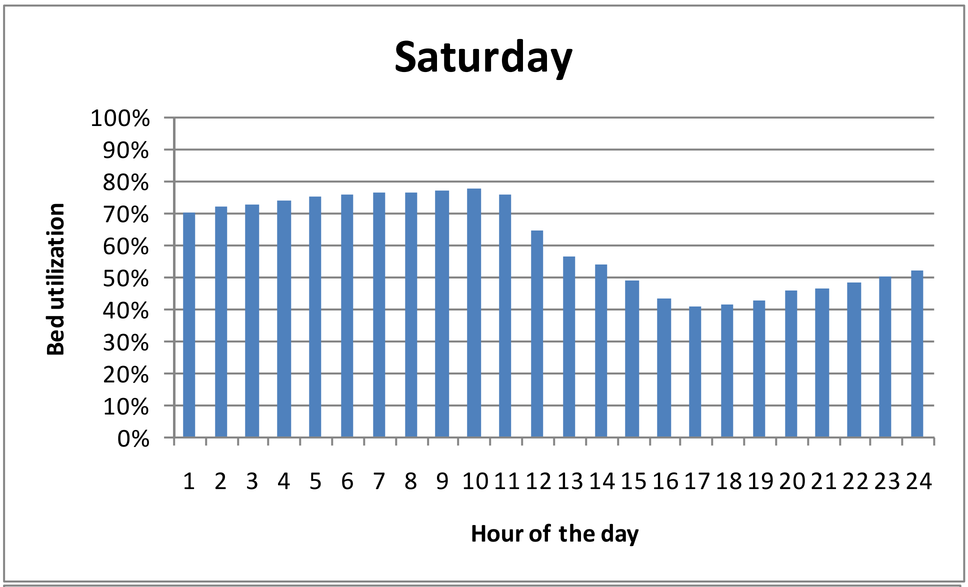


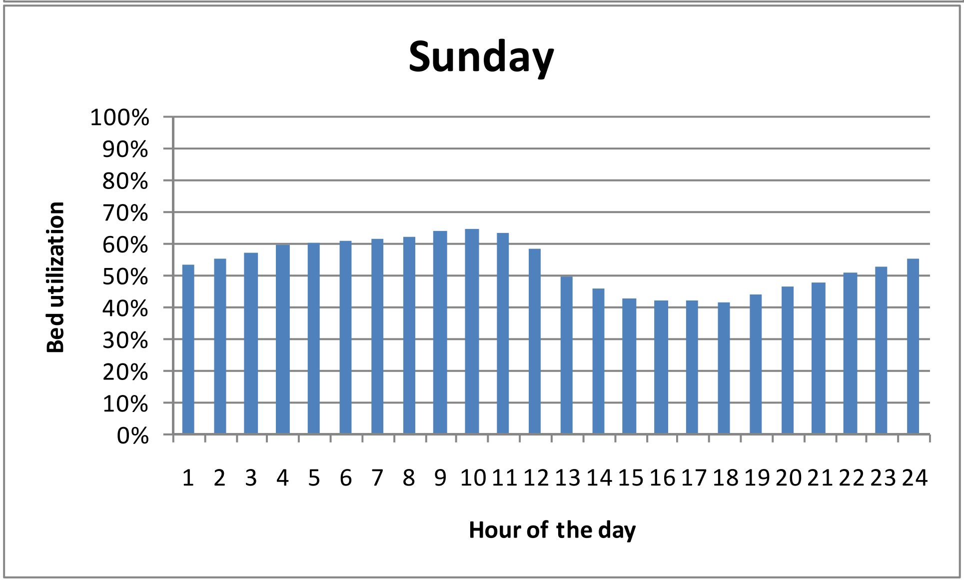



Wednesday
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Bed utilization
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of the day


Thursday
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Bed utilization
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of the day


Friday
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Bed utilization
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of the day


Saturday
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Bed utilization
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of the day


Sunday
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Bed utilization
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of the day

Appendix U Detailed analysis radiology department

Radiology

The second 'other department' that is analysed here is the radiology department. From section 4.5 it is known that only $TN_{i,j,k}$, $TE_{i,j,k}$, and $TR_{i,j,k}$ are used to analyze the time performance of the radiology, all other captured time moments appeared to be invalid. Therefore only three time performance measures can be used: the throughput time, wait time and tardiness. Furthermore section 4.5 showed that not all tests done at the radiology department are normal tests, and are therefore omitted from this analysis. Thus the performance measurers will only be applied to normal tests, which are expected to have a throughput time shorter than 24 hours. Now some general figures on the number of tests will be given first, then the performance measures are assessed with first the throughput time, after that the wait time and finally the tardiness is discussed.

In the period September 1 - November 30 in total 560 (normal) radiology tests were performed. In Table 17 also the numbers per type of radiology test are shown. Of the different radiology tests an X-ray test is performed most often, with 235 tests, then CT, ultra-sound and MRI are performed least for AAU patients.

The throughput time of the different type of tests are listed in Table 17. On average radiology tests have a throughput time of almost 13 hours, with a high standard deviation of 16.7 hours. This indicates that many radiology tests will have a longer throughput time then 24 hours. When the throughput time is considered per type of test, it is clear that Ultra-sounds have the smallest throughput time, then CT and X-ray. MRI has the longest throughput time. The large throughput time for MRI's can be partly explained by the preparation time that is often needed for this type of test. Often contrast agents need to be injected intravenous or taken orally before an MRI can be performed. Another reason for the long throughput time for MRI, is the expected high utilization of this machine. Since an MRI scanner is an expensive machine it needs to be used frequently to make it less costly. Therefore tight schedules are needed, which makes it more difficult to free up time for AAU patients.

Table 17: Sample statistics of the throughput time of radiology tests performed, per type of test

Type of test	Count	Average	Standard Deviation	Coefficient of variation	Minimum	Maximum	Range
X-ray	235	14.50	18.21	125.60%	0.24	71.04	70.80
CT	156	12.34	14.98	121.33%	0.48	70.56	70.08
Ultra-sound	129	9.18	13.67	148.92%	0.24	69.60	69.36
MRI	40	18.90	19.90	105.31%	0.72	67.20	66.48
Total	560	12.99	16.68	128.47%	0.24	71.04	70.80

It was expected that also CT scans would have a larger throughput time, but this does not seem to be true. X-rays however, which are done very often and are better planable, and take most of the time only a few minutes to execute, has a longer than average throughput time. Perhaps the wait time can give more insight into the reason for the long throughput time of X-rays. First the fractions are considered of number of tests performed within 24 hours. The results are shown in Table 18. In total 84% of the tests are ready within 24 hours. This score leaves some room for improvement. When the types of tests are considered individually on can see that the CT and ultra-sounds score around the 90%, whereas X-rays score 81% and MRI 75%. So especially improvement is needed for the X-ray tests, and also for MRI tests, but as discussed improvement will be more difficult there.

Table 18: Fraction of radiology test ready within 24 hours

	X-ray	CT	Ultra-sound	MRI	Total
Service time	0.81	0.88	0.89	0.75	0.84

Now the wait time is analyzed for the different test, this analysis can give insight were improvements are attainable. Note that less observations are analyzed here since 12 tests did not included the $TE_{i,j,k}$

value and could not be analysed. On average it takes 6.44 hours to make the report of the performed test. This is quite long, considering that about 50% of all throughput time is taken to finish the report. However one should be careful with the interpretation of this 50% number, because a few extreme long wait times, there are several values above 60 hours, influence the total wait time disproportionally. Therefore it is better to reflect on the fraction of wait time in relation to the throughput time. This more specific analysis shows on average 36% of all throughput time is spent on wait time, see Table 20. So the impact of extreme long waiting times does influence the average wait time disproportionally. The fractions per type of tests furthermore show some differences, the report time of x-rays is smallest and largest for ultra-sounds. The small fractional wait time for X-rays is to be expected since X-rays reports are quite small and take less time to construct. No reason has been found for the relative longer waiting time of ultra-sounds. Possibly more knowledge is needed of the precise processes done at the radiology department, before sources for delay can be identified.

Table 19: Sample statistics of the radiology wait time per test

Type of test	Count	Average	Standard Deviation	Coefficient of variation	Minimum	Maximum	Range
X-ray	231	5.55	11.74	211.73%	0.00	66.48	66.48
CT	151	6.86	12.04	175.55%	0.00	63.12	63.12
Ultra-sound	127	6.54	10.44	159.67%	0.00	42.96	42.96
MRI	39	9.83	16.23	165.01%	0.00	63.36	63.36
Total	548	6.44	11.93	185.17%	0.00	66.48	66.48

The performance of the radiology department in itself shows many tests that are not finished in time. One possible factor was analyzed, the wait time, the analysis showed that extreme long waiting times influenced the average waiting time disproportionally. Therefore the fraction of wait time per test was analyzed. This showed that the there is room for improvement of the throughput time by reducing the wait time, the time needed to finish up the report of the performed test. This is the internal behavior, but just as with the lab analysis it is more important to see how the radiology department performs in relation to the AAU. Therefore the tardiness is considered next.

Table 20: Sample statistics of the radiology wait time in relation to the throughput time per test

Type of test	Count	Average	Standard Deviation	Coefficient of variation	Minimum	Maximum	Range
X-ray	231	0.27	0.30	110.49%	0.00	0.99	0.99
CT	151	0.38	0.36	95.02%	0.00	0.99	0.99
Ultra-sound	127	0.49	0.36	72.81%	0.00	0.99	0.99
MRI	39	0.36	0.38	105.96%	0.00	0.99	0.98
Total	548	0.36	0.35	96.85%	0.00	0.99	0.99

The tardiness will, as with the clinical lab analysis, discussed at a general level. Figure 27, shows the result of the analysis. The figure is a scatterplot, meaning that all radiology tests are captured in the figure with a dot. The plot displays as if all test were done on the same day. On the x-axis the notice time, is displayed as the hour of the day this test was requested. If a test was requested at 9:00 then the observation of that test will be above the 9 on the x-axis. On the Y-axis the hour of the day at which $TR_{i,j,k}$ is available is displayed. Note that this axis is longer than 24 hours, tests that were finished a day later than the day of request can hereby still be plotted correctly. Think of for instance the test that was requested at 9:00, and has a throughput time of for instance 25 hours, then the test would be ready at hour 34, which is day two at 10:00. Another real example is the observation in the top right corner; this test was requested at 21:42 and had a throughput time of 40.15 hours, which made it finished at hour 61.85 i.e. two days later at 11:51.
The 24 hour line has been added to the graph indicated by the red line. Observations above this line take longer than 24 hours. In the graph also the times at which the visiting rounds are done is captured. The evening visiting round at day 1 and the morning and evening visiting round at day two

is indicated by the yellow line. So for instance all tests that lie under the bottom green line are finished before the evening visiting round on the same day.
Although the 24 hour line is the real norm, it is not hard to understand that the relation to the visiting rounds is more important. In the ideal situation the results of the radiology tests should be available just before the next visiting round. So when a test is requested at 9:00, the results should be available before 16:00. Figure 27 clearly shows that the 24 hour norm is not the best norm to indicate the performance of the radiology AAU relationship. New norms could reflect the relation better.

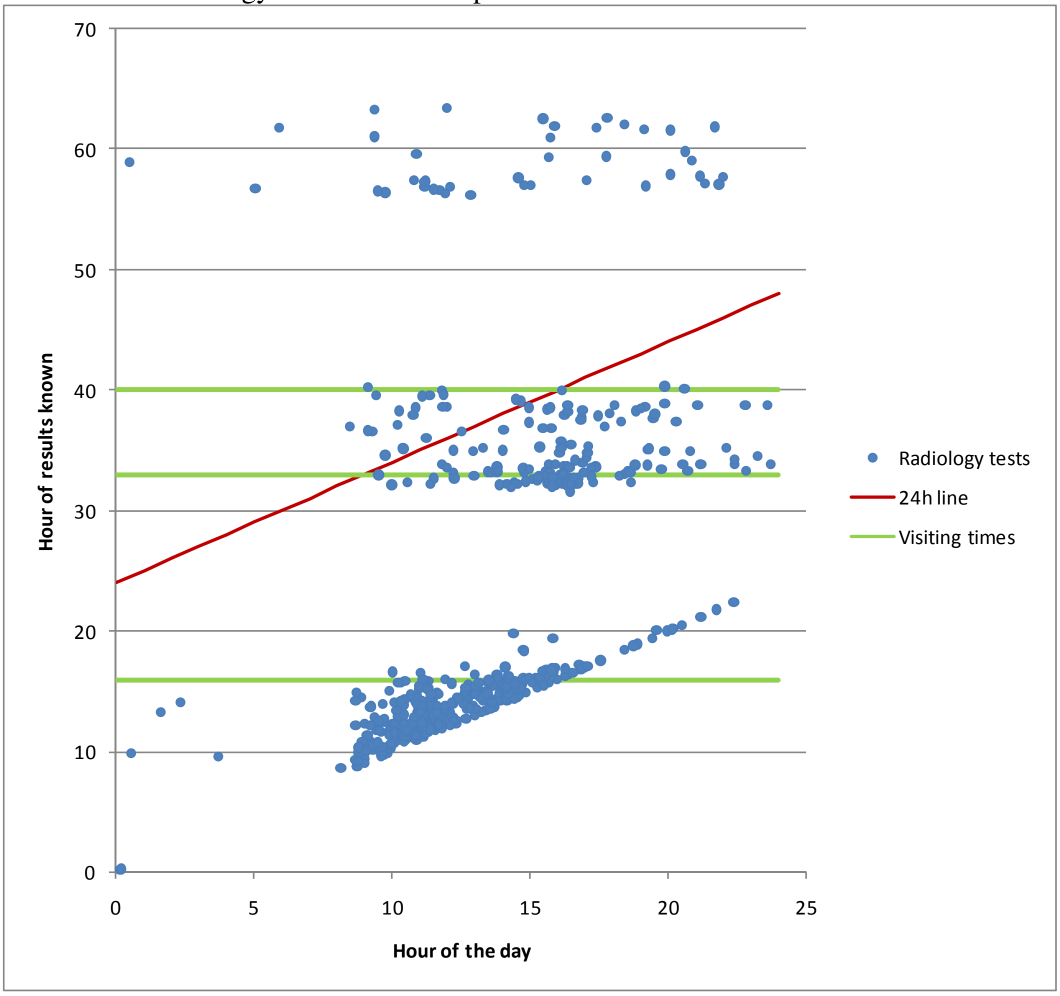


Figure 27: Tardiness scatter plot of radiology tests

There is one thing that must be taken into account with the analysis of the result. These results are strict, meaning that all tests should confirm to the norm, with no exception. It was noticed however that sometimes test were ordered at the AAU, but that the doctor requested the test for the next day, i.e. no rush was needed. It is obvious that these tests are not finished within the time norm set, while they where actually in time, because it was in accordance with the AAU doctor. The dataset does not reflect on these exceptions, while they deteriorate the performance of the radiology. Perhaps a distinction in urgent and normal test could circumvent the credibility discussion of the throughput time.
So to conclude the performance of the radiology must be improved. Too few tests are finished within 24 hours. When a stricter norm is set: the time of result is compared to the time of visiting round, the performance deteriorates even further. So improvements must be made, which could have LoS reductions as a result. The effects, of having the result of a test in time, are similar to that of the laboratory. When results are timely available also the treatment plan can be adjusted sooner. Nevertheless, a better and more detailed assessment of the throughput time is needed to take all relevant aspects into consideration, think of the difference between urgent and normal tests, and only then a complete and reliable performance analysis can be made of the radiology department.

Appendix V Analysis outflow per day of the week

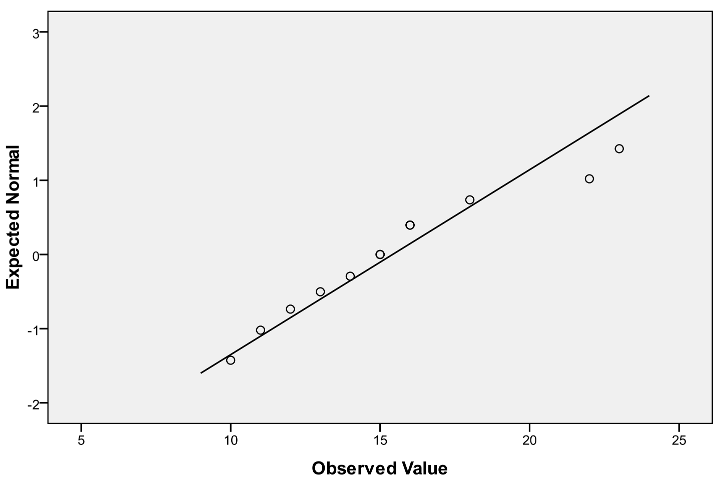
Descriptives

			Statistic	Std. Error
Monday	Mean		15,4167	1,15770
	95% Confidence Interval for Mean	Lower Bound	12,8686	
		Upper Bound	17,9648	
	5% Trimmed Mean		15,2963	
	Median		15,0000	
	Variance		16,083	
	Std. Deviation		4,01040	
	Minimum		10,00	
	Maximum		23,00	
	Range		13,00	
	Interquartile Range		5,25	
	Skewness		,739	,637
	Kurtosis		,015	1,232
Tuesday	Mean		18,3333	1,23296
	95% Confidence Interval for Mean	Lower Bound	15,6196	
		Upper Bound	21,0471	
	5% Trimmed Mean		18,4259	
	Median		18,0000	
	Variance		18,242	
	Std. Deviation		4,27112	
	Minimum		11,00	
	Maximum		24,00	
	Range		13,00	
	Interquartile Range		8,50	
	Skewness		-,200	,637
	Kurtosis		-1,223	1,232
Wednesday	Mean		18,3333	1,24519
	95% Confidence Interval for Mean	Lower Bound	15,5927	
		Upper Bound	21,0740	

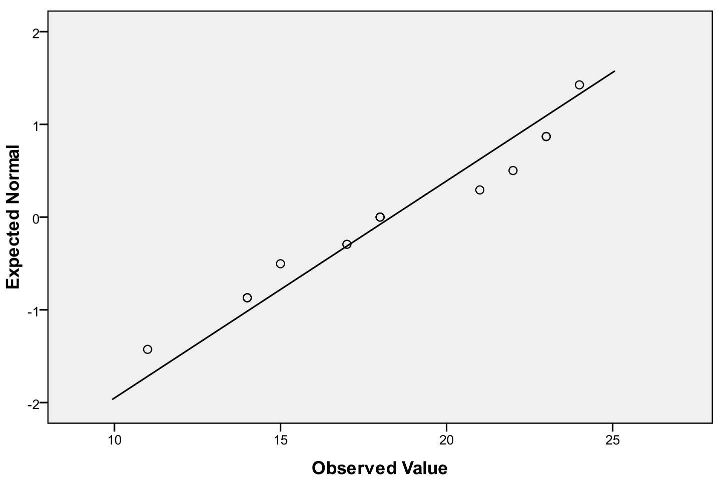
	5% Trimmed Mean	18,4259	
	Median	18,0000	
	Variance	18,606	
	Std. Deviation	4,31347	
	Minimum	11,00	
	Maximum	24,00	
	Range	13,00	
	Interquartile Range	7,00	
	Skewness	-,192	,637
	Kurtosis	-1,109	1,232
Thursday	Mean	18,2500	1,03078
	95% Confidence Interval for Mean Lower Bound	15,9813	
	Upper Bound	20,5187	
	5% Trimmed Mean	18,2778	
	Median	17,5000	
	Variance	12,750	
	Std. Deviation	3,57071	
	Minimum	12,00	
	Maximum	24,00	
	Range	12,00	
	Interquartile Range	5,00	
	Skewness	,330	,637
	Kurtosis	-,103	1,232
Friday	Mean	21,9167	1,04779
	95% Confidence Interval for Mean Lower Bound	19,6105	
	Upper Bound	24,2228	
	5% Trimmed Mean	21,8519	
	Median	22,0000	
	Variance	13,174	
	Std. Deviation	3,62963	
	Minimum	16,00	
	Maximum	29,00	
	Range	13,00	
	Interquartile Range	4,75	

	Skewness		,121	,637
	Kurtosis		,107	1,232
Saturday	Mean		16,9167	1,24595
	95% Confidence Interval for Mean	Lower Bound	14,1743	
		Upper Bound	19,6590	
	5% Trimmed Mean		16,9074	
	Median		17,0000	
	Variance		18,629	
	Std. Deviation		4,31611	
	Minimum		10,00	
	Maximum		24,00	
	Range		14,00	
	Interquartile Range		5,75	
	Skewness		,264	,637
	Kurtosis		-,286	1,232
Sunday	Mean		12,2500	1,18785
	95% Confidence Interval for Mean	Lower Bound	9,6356	
		Upper Bound	14,8644	
	5% Trimmed Mean		11,8333	
	Median		11,0000	
	Variance		16,932	
	Std. Deviation		4,11483	
	Minimum		8,00	
	Maximum		24,00	
	Range		16,00	
	Interquartile Range		2,50	
	Skewness		2,369	,637
	Kurtosis		6,735	1,232

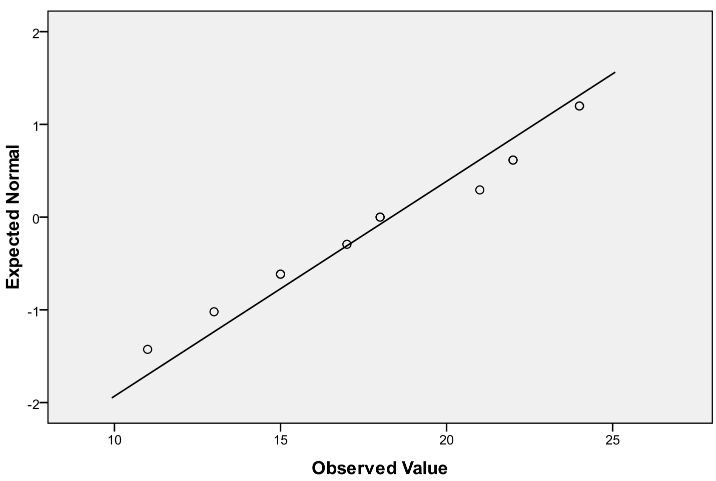
Normal Q-Q Plot of Monday



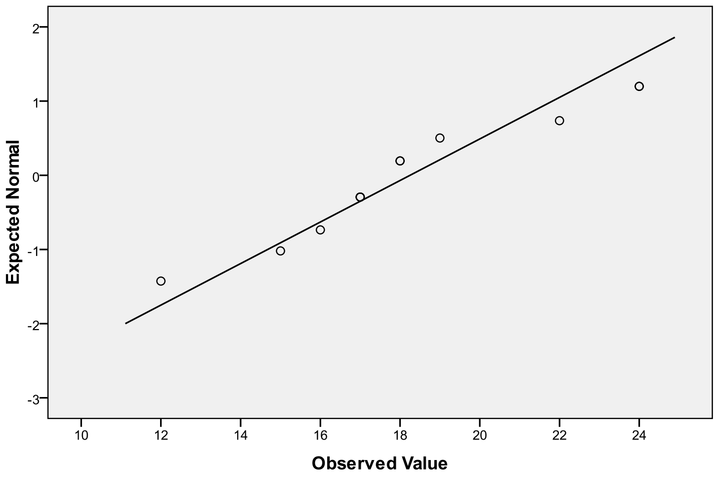
Normal Q-Q Plot of Tuesday



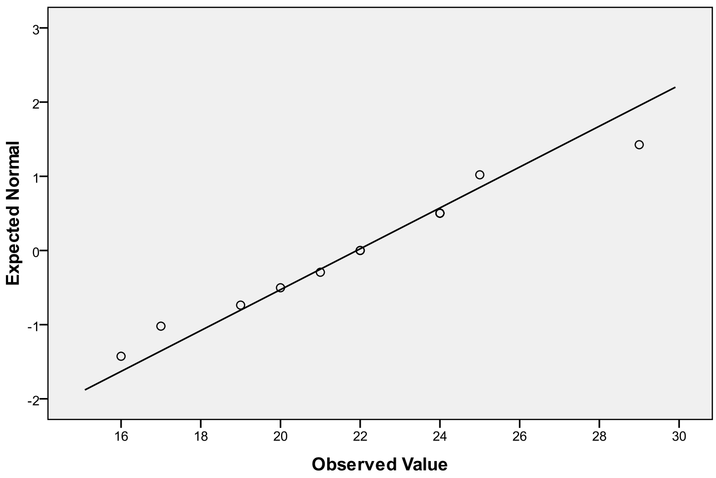
Normal Q-Q Plot of Wednesday



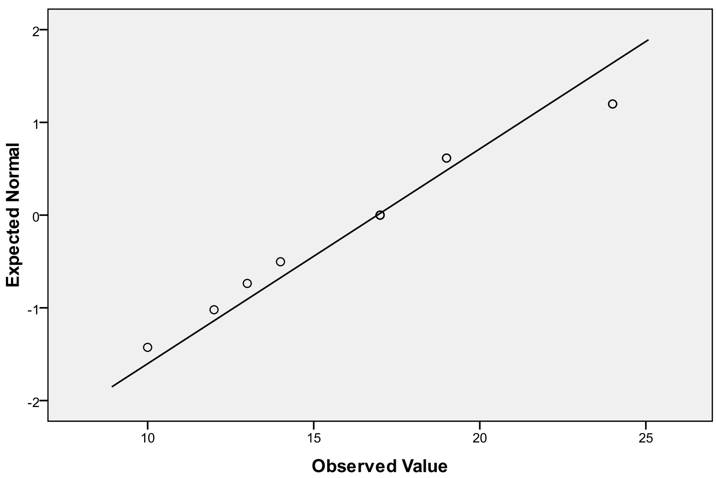
Normal Q-Q Plot of Thursday

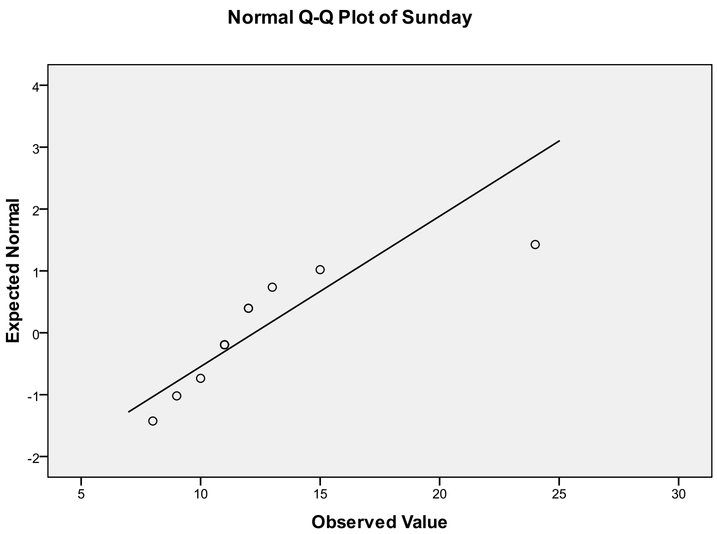


Normal Q-Q Plot of Friday



Normal Q-Q Plot of Saturday





Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Monday	,192	12	,200*	,932	12	,406
Tuesday	,150	12	,200*	,936	12	,444
Wednesday	,148	12	,200*	,944	12	,549
Thursday	,195	12	,200*	,928	12	,362
Friday	,134	12	,200*	,971	12	,922
Saturday	,174	12	,200*	,937	12	,460
Sunday	,274	12	,013	,736	12	,002

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Descriptives

			Statistic	Std. Error
Sunday	Mean		11,1818	,56918
	95% Confidence Interval for Mean	Lower Bound	9,9136	
		Upper Bound	12,4500	
	5% Trimmed Mean		11,1465	
	Median		11,0000	
	Variance		3,564	
	Std. Deviation		1,88776	
	Minimum		8,00	
	Maximum		15,00	
	Range		7,00	
	Interquartile Range		2,00	
	Skewness		,336	,661
	Kurtosis		,907	1,279

Appendix W Outflow per destination

Outflow analyzed per destination

The analyses of the outflowing patients at the AAU per week, day and hour made no distinction between transferred and discharged patients. Though, this distinction is very important. Not only to check if the performance levels set, regarding the percentage of discharge patients at the AAU, are attained, but also to gain more insight in the outflow of patients at the AAU, and with it also gain more insight in the inflow of patients at regular wards. From practice it is known that there are differences between the discharge and transfer moments, these will be shown here. First, insight will be given in the fraction transferred or discharged patients, then, the outflow patterns per week, weekday and hour are assessed subdivided per destination. Finally, the group of transferred patients is further investigated, their specific destination ward will be assessed.

One of the reasons to create an AAU at the MMC, was to decrease the average LoS of acute patients. In section 5.1, it was examined if the LoS of acute patients had been reduced after September 1, the day the AAU opened. It was found, that on average the LoS had decreased, mainly due to reductions in LoS for the specialties ACH and INT. The subset of that analysis was acute patients. Here the subset of analysis is restricted to AAU patients only. For AAU patients it is determined what fraction of patients is discharged from the AAU and how the hospital LoS of AAU patients is distributed, with a focus on the fraction discharged within 48 hours.
With the design of the AAU it was projected that in general 40 percent of the AAU patients should be discharged at the AAU. Of all outflowing patients at the AAU in September, October and November, almost 46% was discharged at the AAU. This is somewhat higher than the goal of 40%, so an adequate number of patients is discharged at the AAU.
With the design of the AAU, also the hospital LoS was also projected. With the set-up of the AAU especially the fraction patients discharged within 48 should increase. In Table 21, the hospital LoS per specialty is shown in cumulative fractions, the ambition level and the actual lengths of stay after September are also displayed. The same type of table is found in Table 25, but here the LoS percentages are given per month. In Table 21 can be seen that most specialties conform to the projected fraction of AAU patients discharged within 48 hours. Only ORT seems largely behind the projection. Only 32% of the AAU-ORT patients are discharged within 48 hours, while it was projected that 45% of the patients were discharged. Furthermore PUL scores somewhat lower than the projection, ACH just a fraction under its projection. INT, MDL and URO score all around 10% higher as the projected values. So these specialties perform well. However, keep into account the findings of section 5.1: the ambitions set per specialty aren't equally difficult per specialty. Some specialties already conformed to the new norms in the period before 1 September and need to perform better than the ambition to improve its performance.
In Table 25, the average LoS numbers and the cumalitive fractions are displayed per month. This shows a decrease in fraction of AAU patients discharged within 48 hours. This is in line with the findings of the AAU LoS analysis that the fraction of patients away at the AAU within 48 hours decreased in November. As is also indicated there, this decrease does not immediately bare concerns, since one out of three months is too little data. All in all the fraction of patients discharged within 48 hours seems in most cases at or above the projected levels.

To have a more complete view of what happens to the patients that stay longer at the AAU, are the transferred or discharged, now the discharge fractions per week are considered. In Figure 28 the weekly discharge/transfer fractions have been visualised. In this figure can be seen that the fraction of AAU patients that are discharged deviate around 45%, with a variation of plus and minus 5%. Furthermore the expected ditch in number of patients discharged in the month November does not seem present. The on average longer AAU LoS in November probably caused relatively more patients to be discharged after 48 hours. These patients are not visible in the above analysis, this further grounds the conclusion not to worry about the lower percentage of patients discharged within 48 hours.

Table 21: Hospital LoS of AAU patients in cumulative fractions divided in days

Specialty	Period	n	avg	0-1 days	1-2 days	2-5 days	5-10 days	10-15 days	15-30 days	30-100 days	100-100+ days
ACH	Ambition			0.20	0.50	0.65	0.85	0.92	0.97	1.00	1.00
	During	403	6.17	0.27	0.49	0.69	0.85	0.90	0.96	1.00	1.00
INT	Ambition			0.15	0.30	0.50	0.75	0.88	0.97	1.00	1.00
	During	402	7.15	0.20	0.40	0.56	0.79	0.87	0.97	1.00	1.00
MDL	Ambition			0.10	0.30	0.55	0.80	0.90	0.97	1.00	1.00
	During	176	5.82	0.18	0.44	0.64	0.84	0.91	0.97	1.00	1.00
NEU	Ambition										
	During	89	5.81	0.35	0.53	0.75	0.87	0.90	0.98	1.00	1.00
ORT	Ambition			0.20	0.45	0.55	0.75	0.85	0.95	0.99	1.00
	During	119	8.71	0.18	0.32	0.46	0.71	0.82	0.95	1.00	1.00
PUL	Ambition			0.10	0.30	0.40	0.70	0.90	0.98	1.00	1.00
	During	187	7.80	0.11	0.26	0.43	0.79	0.86	0.96	1.00	1.00
URO	Ambition			0.10	0.30	0.70	0.95	0.96	0.99	1.00	1.00
	During	114	4.53	0.18	0.41	0.71	0.91	0.96	0.99	1.00	1.00

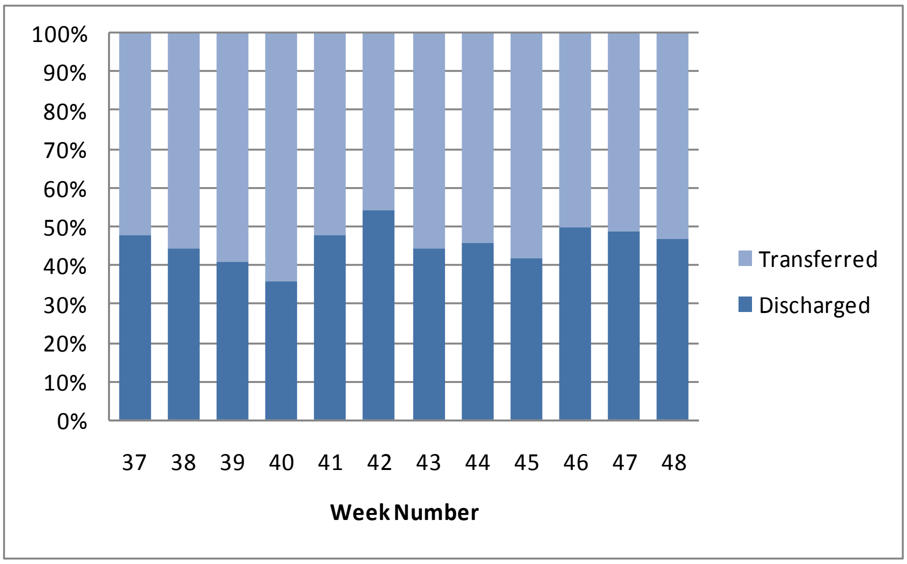


Figure 28: Percentage of discharged vs transferred AAU patients per week

Figure 29 shows the percentage of patients transferred/discharged per day of the week. The figure shows a relatively lower percentage of discharges on Sunday, Monday and possibly lower on Tuesday. These lower discharge percentages are caused by more ill patients flowing in at weekends. Relatively more patients admitted during weekends, will be transferred to other wards in MMC. Thus although at weekends less AAU patients flow in, relatively more are transferred to other wards.

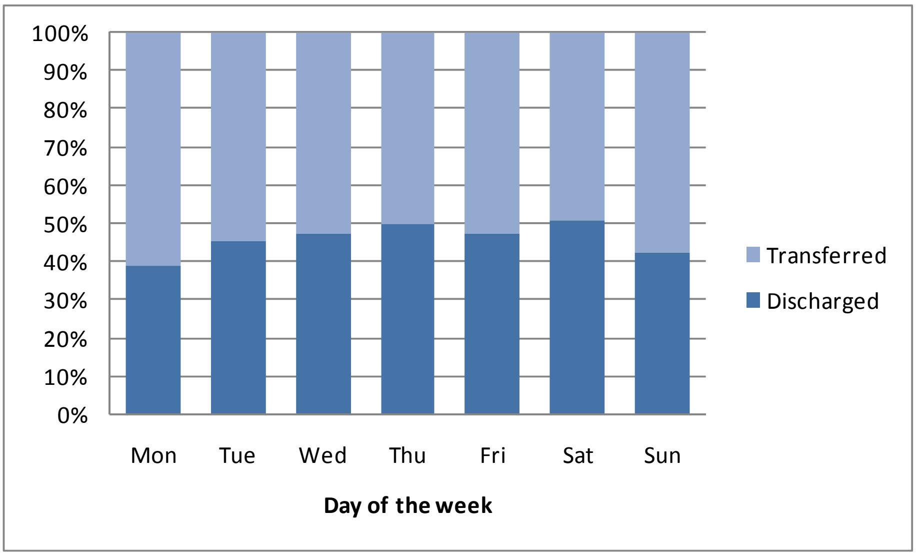


Figure 29: Percentage of discharged vs transferred AAU patients per day of the week

Outflow to departments

Somewhat more than 50% of all AAU patients are transferred to other MMC wards when they are sent away at the AAU. In previous paragraphs the precise moment of transfer was shown. Here, the destination of the transferred patient is assessed: to which department are AAU patients transferred and is this in accordance with the specialty of the patients.

The number of transfers specified per department in the months September, October and November are stated in Table 22. The departments which received the most transferred patients from the AAU are 3A, 3C and 3D. These departments combined receive about 50% of the transferred patients. Furthermore, also many transfers are done to 2A, 2B and 2D. Other departments receive relatively fewer patients. The variation in inflow of patients at the different departments is rather low throughout the months; the values of transferred patients per department do not deviate much. This could suggest that the number of admissions at regular wards is predictable. More research into this topic, e.g. the weekly and daily inflow of patients, is needed to fully understand the inflow of AAU patients at regular wards.

Table 22: Destination department of transferred patients per month

Discharge	Month			
Department	9	10	11	Grand Total
080D	11	10	14	35
090D	2	3	4	9
1D	3	4	7	14
2A	28	36	35	99
2B	29	34	18	81
2C	2	2	3	7
2D	33	43	38	114
3A	53	47	56	156
3B	18	22	16	56
3C	40	48	46	134
3D	50	41	47	138
IC	5	2	4	11
Grand Total	274	292	288	854

Table 23: Medical specialty of the regular wards

Discharge Department	Specialties
080D	ACH, ORT, PUL
090D	ACH, ORT
1D	
2A	ACH
2B	ACH
2C	
2D	ORT, URO
3A	PUL
3B	NEU
3C	INT
3D	INT, MDL
IC	

One of the quality performance measures is the percentage of patients that is transferred to appropriate wards. Patients from a certain specialty are in principle transferred to wards that are specialized in their specialty. In Table 23 a list is stated of medical specialties per principal destinations of the patient, note that only the seven largest specialties of AAU patients are included in this list. When no specialty is stated, it is not the principal department for the subset of these specialties, in case of 1D and 2C, or is accessible to all specialties, in case of the IC. Now it is analysed to see if the majority of the patients are transferred to principal wards.
In Table 24 the numbers are shown of transferred patients from the seven largest specialties, specified per destination department. In this table the combinations of medical specialty with principle transfer departments are shaded; all numbers outside these shaded cells indicate transfers of patients to non-principle departments.

According to Table 24 the majority of patients are transferred to a ward that matches the patient's specialty. Per specialty about 85% of the patients are transferred to principle departments. MDL scores somewhat lower, but several MDL patients are transferred to 3C an INT department. When these MDL patients are added to the appropriate transfers then also MDL scores around the 80%. Thus the existence of transfers to non-principal departments is present for almost all medical specialties and concerns about 15% of the patient.

Table 24: Destination department of transferred patients per specialty

Discharge	AAU specialty of discharge							
department	ACH	INT	MDL	NEU	ORT	PUL	URO	Grand Total
080D	17				5	13		35
090D	1				7			8
1D	3	3				1	2	9
2A	85	4	4		3	1	2	99
2B	69	1	4		2	1	3	80
2C	2	1					1	4
2D	9	6	1		48		48	112
3A	3	14	4	1		127	2	151
3B	2	7	5	39	1	2		56
3C	2	117	13			1	1	134
3D	1	74	59	1	1		2	138
IC	3	4	1			2		10
Grand Total	197	231	91	41	67	148	61	836

Table 25: Hospital LoS of AAU patients in cumulative fractions per month

Specialty	Time period	n	average	0-1 days	1-2 days	2-5 days	5-10 days	10-15 days	15-30 days	30-100 days	100+ days
ACH	Ambition			0.20	0.50	0.65	0.85	0.92	0.97	1.00	1.00
	Sept	132	5.69	0.22	0.51	0.73	0.87	0.91	0.96	1.00	1.00
	Oct	142	6.29	0.30	0.52	0.65	0.85	0.89	0.95	1.00	1.00
	Nov	129	6.54	0.29	0.43	0.67	0.83	0.89	0.95	1.00	1.00
INT	Ambition			0.15	0.30	0.50	0.75	0.88	0.97	1.00	1.00
	Sept	143	6.63	0.24	0.43	0.59	0.81	0.90	0.98	1.00	1.00
	Oct	132	7.30	0.19	0.47	0.60	0.79	0.86	0.94	1.00	1.00
	Nov	127	7.56	0.16	0.30	0.48	0.76	0.84	0.98	1.00	1.00
MDL	Ambition			0.10	0.30	0.55	0.80	0.90	0.97	1.00	1.00
	Sept	63	6.31	0.16	0.37	0.51	0.83	0.94	0.97	1.00	1.00
	Oct	58	5.67	0.21	0.48	0.71	0.84	0.90	0.97	1.00	1.00
	Nov	55	5.41	0.16	0.47	0.73	0.84	0.91	0.98	1.00	1.00
NEU	Ambition										
	Sept	30	5.57	0.53	0.70	0.83	0.90	0.93	0.97	1.00	1.00
	Oct	29	7.64	0.28	0.38	0.59	0.79	0.86	0.97	1.00	1.00
	Nov	30	4.28	0.23	0.50	0.83	0.90	0.90	1.00	1.00	1.00
ORT	Ambition			0.20	0.45	0.55	0.75	0.85	0.95	0.99	1.00
	Sept	39	8.79	0.18	0.41	0.56	0.69	0.87	0.90	1.00	1.00
	Oct	37	8.99	0.19	0.27	0.38	0.76	0.86	0.95	1.00	1.00
	Nov	43	8.40	0.19	0.28	0.44	0.67	0.74	1.00	1.00	1.00
PUL	Ambition			0.10	0.30	0.40	0.70	0.90	0.98	1.00	1.00
	Sept	48	8.56	0.06	0.17	0.35	0.75	0.85	0.94	1.00	1.00
	Oct	67	7.92	0.10	0.31	0.43	0.76	0.85	0.97	1.00	1.00
	Nov	72	7.18	0.15	0.28	0.47	0.83	0.86	0.97	1.00	1.00
URO	Ambition			0.10	0.30	0.70	0.95	0.96	0.99	1.00	1.00
	Sept	38	3.70	0.21	0.39	0.71	0.97	1.00	1.00	1.00	1.00
	Oct	44	5.66	0.11	0.43	0.64	0.84	0.95	0.98	1.00	1.00
	Nov	32	3.96	0.22	0.41	0.81	0.94	0.94	1.00	1.00	1.00

Appendix X AAU detail analysis

At the end of patients' stay at the AAU a decision is made where the patient should go. Is it safe for the patient to leave the hospital and be discharged, or does the patient need to be transferred to another ward at the MMC and receive further care. In case of a discharge, the patient can leave the hospital relatively fast, sometimes transportation and/or home care needs to be arranged, but often the patient can leave the hospital instantly. If a patient needs to be transferred, more arrangements need to be made: a bed needs to be arranged at an appropriate ward, and an appointment needs to be made with the receiving ward regarding the time of transfer. During these actions the patient is still admitted to the AAU and is waiting for its transfer. Although this extra waiting time is needed to make all transfers from the AAU planable, it is investigated if this time is not needlessly long.

In this paragraph the moment of transfer decision AD_j, the moment of known transfer location AR_j and the moment of planned transfer AP_j are analysed. During the month November these time moments were registered by AAU nurses. Since data recording by hand has its limitations, the quality of the data is also assessed. After the assessment of the different time moments separately, the performance measures linked to these time moments will be considered. These are: Queue time and true queue time.

AD

The first time moment which is assessed is the decision time of end of stay at the AAU; the time at which the doctors decide the patient can be discharged or transferred to another ward at MMC. As discussed, AD_j is captured by nurses on paper and later entered in the computer. Therefore, the quality of the data is assessed, first. After that the time moment is analyzed.

In the researched period, October 28 till November 30, 615 patients were admitted to the AAU. Thus. The AD time moment was captured of 189 patients. Thus the AD time was gathered for only 30% of the patients. Although a low percentage of completed times can be expected when filling in forms on paper, a percentage of 30% is somewhat low. The low fill out percentage can be explained by the errors made when filling in the forms. Much more data was gathered by Nurses, but numerous times the precise time of transfer wasn't registered. Often, only the ward was captured to which the patient was transferred, not the time of transfer or discharge. In these cases no data of the patients was gathered and has resulted in little workable data.

The reason for the errors made when filling out the forms, have presumably two reasons. First, despite the care that was taken with the introduction of the forms, not all nurses knew how to fill in the forms. Also the check performed at the start of each shift, asking the spot nurse if they understand the form, did not have the expected results. Second, the spot nurse did not always have enough time to fill out the form correctly. Although the AAU had been operational for several months, not all nurses had already performed a spot duty when the detailed data gathering started. So several nurses were not only unfamiliar with the data gathering, but were also unfamiliar with the spot duty. This has limited the success of gathering of the detailed data greatly.

Since only a small percentage of usable data has been gathered, the generability of the data can be at stake. The generalibility is therefore checked in one way. It is checked if the values are equally spread over the investigated period. When all usable data is gathered in for instance one week of the inspection period, the gathered data is not representable for the complete period. A scatter plot to test the generability of the AD data can be found in Figure 30. As can be seen in the plot, no values are present in the last week of data gathering, also the week before last has only limited number of usable data available. During the first three weeks in which many data was gathered also a pattern can be identified; only few data were filled out at weekends. The analysis shows that the generability of the data is limited; usable data is only available of a period of three weeks and almost no data is present in weekends. The reason for this can be explained by the lack of attention given to the nurses by the researcher. At weekends, the researcher was not present at the AAU, and in the last few weeks no personal attention was given to the spot nurse at the start of their shift. The assumption that the nurses did understand how to fill out the forms after the first three weeks and less attention was needed, proved to be wrong. Although the researcher was present at the AAU also during the last 2 weeks of the inspection period, questions were rarely asked. In the remainder of this section care should be taken with the interpretation of the results, since almost no data is available for weekend, and only three weeks of data is available.

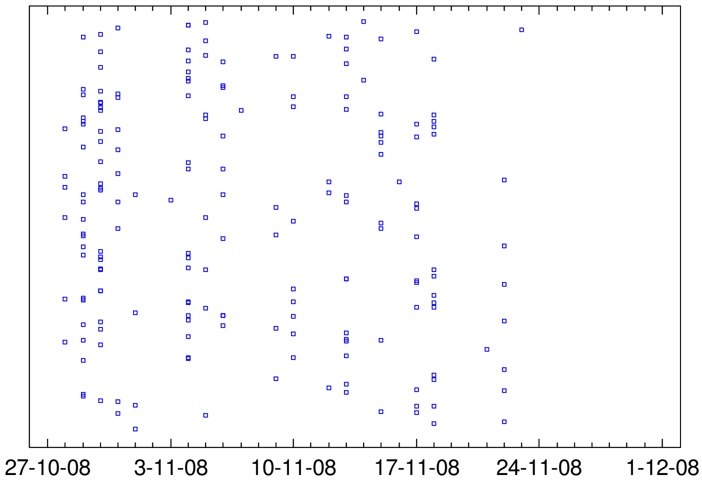


Figure 30: Distribution of the AD time moments captured in the inspected period

The discharge and transfer decisions made by doctors are likely to happen around the time they do their ward rounds, so around 9:00 and 16:00. The scatter plot in Figure 31, seems to confirm part of this. Many transfer decisions are taken around 9:00, however only few decisions are taken around 16:00. To be more precise, of all 189 end of stay decisions only 36 were done after 12:00. The sample statistics in Table 26 also confirms this with an average AD time of 10:15. So, the morning visiting rounds are the most fruitful in terms of end of stay decisions, i.e. only a limited amount of end of stay decisions are taken with the afternoon visiting round.

There is however an explanation for the few end of stay decisions in the afternoon. If the inflow pattern per hour of the day at the AAU is taken into consideration, see Figure 10, one can see that most patients arrive after 12:00. So many patients who stay at the AAU around the evening visiting round are just admitted to the AAU, it is not likely that in a few hours an end of stay decision is been taken. Furthermore, after 18:00, when most visiting rounds are already finished, still a considerable amount of patients needs to be admitted. So there simply aren't many patients for whom an end of stay decision can be taken. Therefore the effectiveness of the evening visiting round in terms of number of end of stay decisions is lower for the afternoon visiting round as for the morning visiting round.

Still the result of the analysis are worrying, although less end of stay decisions are to be expected with the evening visiting round, the amount is very low. This suggests that those visiting round are less effective. It was already shown that the start time of the afternoon visiting round is in many cases later as agreed, and has much variation. How and if these two results are related cannot be stated, but it is at least remarkable that the visiting round is done poorly and only few end of stay decisions are made.

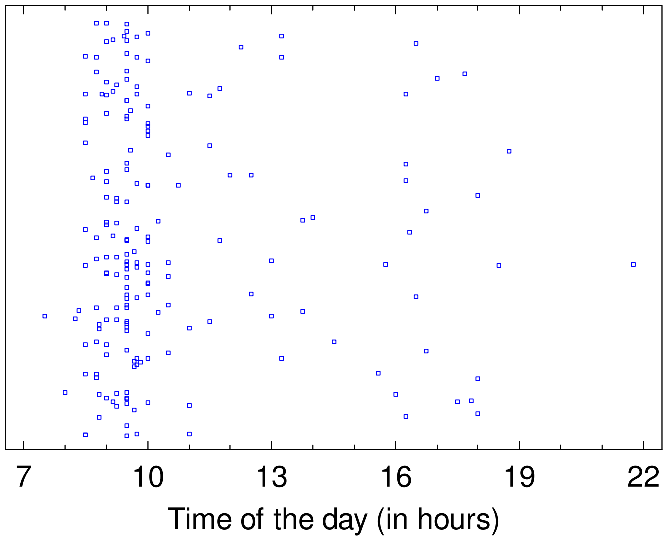


Figure 31: Scatterplot of time of AD

Table 26: Sample statisctics of AD

Statistic	Value
Count	189
Average	10.28
Standard deviation	2.72
Coeff. of variation	26.46%
Minimum	7.00
Maximum	21.00
Range	14.00
Stnd. skewness	10.00
Stnd. kurtosis	6.50

AR & AP

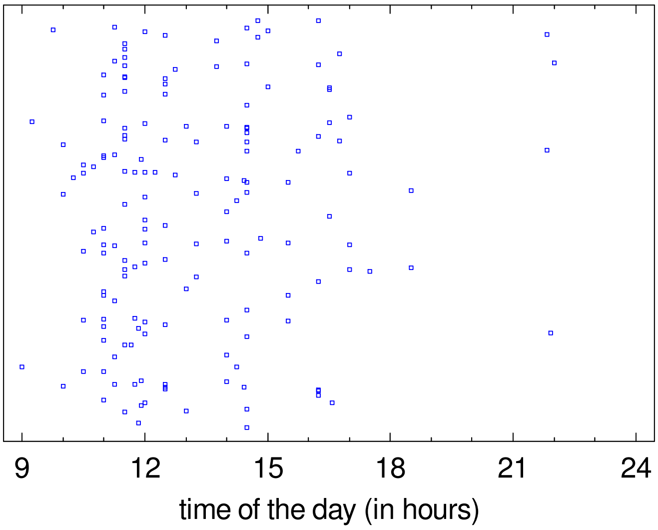
When the end of stay decision has been taken, the patient has to wait till the patient really leaves the AAU, or is transferred to other wards. The AR time, the moment when the ward of transfer is known, and the AP time, the planned time of transfer, only applies to patients who are transferred to regular wards of MMC. Not all patients, of whom detailed data is available, were transferred to other wards. This has resulted in even fewer available data of the AR and AP than for the AD time moments. All other limitations that were discovered with the AD analysis, think of the issue of generability, also apply to the AR and AP data.

Beside the generability limitation, also the validity of the AR and AP data is at stake. When the data was entered in Excel, it was found that the AR time was often mistaken for the AP time, and sometimes the AP was also mistaken for the AE time. One indication for this is that the AR and AP were equal several times, furthermore the AP time was smaller than the AR time. This is impossible for both, since first the AAU has to be informed by the admissions department before the patient can be transferred. Another indication for the validity problem, is the time moments for AR. Often, the AR time was equal to 14:30. 14:30 is a popular time for the planned time of transfer, so it is very likely that for these patients the AR time was registered incorrectly.

The wrong interpretation of the AR and AP time moments is due to several reasons. First, nurses expected to register the real moment of transfer since this is an important time, however this moment was already captured with the use of EZIS. Another reason for the mix up is the seemingly unimportance and indistinct of the AR time moment. Many nurses did not know how to interpret the AR moment. This has further degraded the validity of the AR and the AP time moment. Both reasons suggest that the introduction of the data gathering method with the nurses has not been flawless.

Because the performance measures related to AR and AP can not be determined in a valid way they will not be present in this report. Nonetheless, the captured time moments in itself do offer insight and have therefore been included in the appendix. The general statistics and scatter plots of these time moments can be found below.

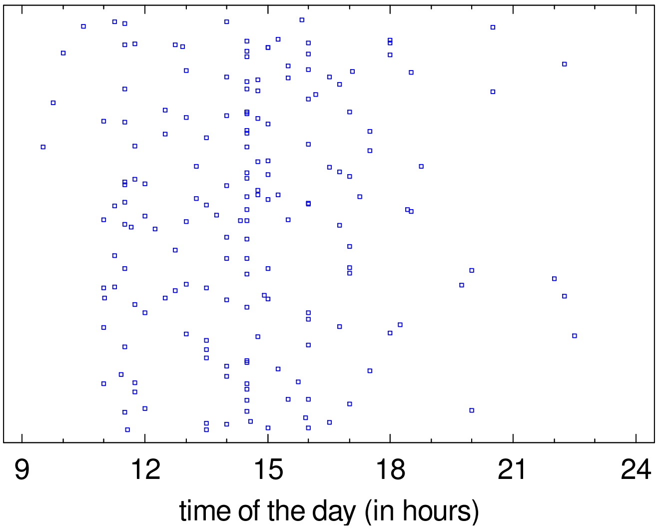
AR (scatterplot)



Summary Statistics for AR_hour*24

Statistic	Value
Count	158
Average	13.24
Standard deviation	2.50
Coeff. of variation	18.88%
Minimum	9.00
Maximum	22.00
Range	13.00
Stnd. skewness	6.26
Stnd. kurtosis	4.80

AP (scatterplot)



Summary Statistics for AP_hour*24

Statistic	Value
Count	176
Average	14.58
Standard deviation	2.54
Coeff. of variation	17.43%
Minimum	9.50
Maximum	22.50
Range	13.00
Stnd. skewness	3.61
Stnd. kurtosis	1.92

Performance Measures related to detailed AAU data

The detailed AAU data is used to determine the flow out time, queue time and true queue time. Yet, in the previous paragraph it was found that AR and AP lack generability and validity and were therefore excluded from analysis. This means that two of the three time performance measures, aren't included. This applies to the performance measure of queue time: AE_j - AR_j and the true queue time performance measure $\max\left[0,\left(AE_j - AP_j\right)\right]$. The only detailed AAU performance measure which is still used, is the flow out time AE_j - AD_j. This measure reflects on the total time it takes, from the moment the doctor decides the patients' stay at the AAU can end, till the time the patients is digitally transferred or discharged from the AAU. This performance measure includes two separate processes: the search for a bed at an appropriate ward by the admissions department and the waiting time before the patient can be transferred to the destination ward to make the transfer, for both sending and receiving, as apposite as possible.

The analysis of the flow out time can be found in the cumulative plot in Figure 32, and the sample statistics in Table 27. One can see that for this analysis 175 values were used. This is slightly less than the AD analysis, the reason for this is that some AD values appeared to be wrongly registered or entered in excel resulting in negative out flow times, which is not possible.

In the quantile plot, see Figure 32, three blocks of values can be identified. The first block of values, indicate patients who left within about 10 hours after the end of AAU stay decision was taken. Consequently, these patients flew out on the same day as the end of AAU stay decision was taken. The second patient group starts at hour 20 continuing to hour 34. These patients represent 15 percent of the inspected sample, and had to wait a day and night before they could leave the AAU. The final group contains patients who probably had to wait two days and two nights before they left the AAU. This group contains slightly less than 4 percent of the inspected population. The attentive reader could have found a fourth group, since the largest flow out time is almost 62 hours. Though, this 'group' is made up of only one observation and is therefore left out of the analysis here.
Of these three groups, group two and three are the most worrying. These groups, who contain about 20% of the sample population, have to wait more than one day before they can leave the AAU. This can either mean that no bed was available at an appropriate ward, or the discharge of the patient was postponed. Since a distinction between discharged and transferred patients will increase the understanding of the data, an analysis of the separate groups is made below.

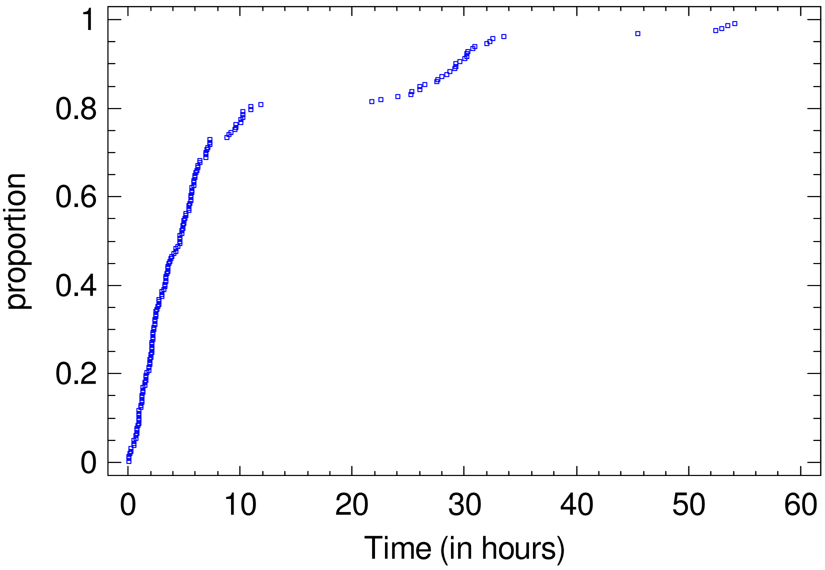


Figure 32: Quantile plot of flow out time

Table 27: Sample statistics of flow out time

Statistic	Value
Count	175
Average	9.41
Standard deviation	12.49
Coeff. of variation	132.78%
Minimum	0.05
Maximum	61.95
Range	61.90
Stnd. skewness	11.10
Stnd. kurtosis	10.52

The analysis of flow out time per destination shows some unexpected behaviour. The group of discharged patients has on average a longer flow out time, probably caused by several flow out times for discharged patients which are larger than 10 hours. This behaviour can be explained either by patients who were about to be discharged, but needed to stay since their condition did not improved enough, or because there home situation did not allow for their discharge, or can be explained by patients that were to be transferred, but because no appropriate bed was available at other wards, these patients lengthened their AAU stay and were discharged later at the AAU. In all cases their real reason for the discharge delay cannot be determined. But it is clear that discharged patients normally do not have to wait more than 1 day before they can be discharged.
Then the group of transferred patients is discussed, on average it takes 8.6 hours to transfer a patient, and several patients had to wait more than one day before they could be transferred. This is worrying, since those patients occupied a bed at the AAU longer then needed. However one of the intended functions of the AAU, creating a buffer before the regular wards to safeguard planned transfers, could induce such behaviour. Further analysis was done for the transferred patients who had a longer flow out time than 20 hours, but did not result in more insight. No commonalities were found in for instance the date of discharge, specialty of discharge, or transferred ward. Furthermore there was no correlation between the utilization level at the most likely receiving wards and the flow out time. So, there was no prove, that the transfer delays were caused by high utilization levels at receiving wards.

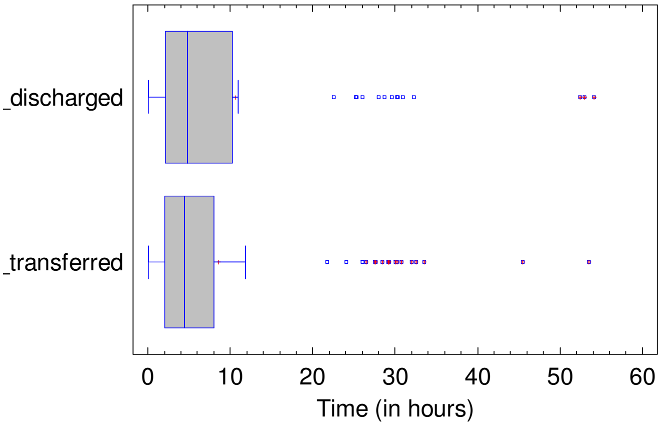


Figure 33: Boxplot of flow out time per destination

Table 28: Sample statistics of flow out time per destination

	DischargeWord	
Statistic	Discharged	Transferred
Count	71	104
Average	10.62	8.58
Standard Deviation	14.38	11.02
Coeff. of variation	135.31%	128.48%
Minimum	0.08	0.05
Maximum	61.95	53.48
Range	61.87	53.43
Stnd. Skewness	6.90	8.07
Stnd. Kurtosis	6.02	6.59

There remains only one analysis regarding the flow out time. Although no reasons have been identified that lead to longer flow out times, and thus no recommendations can be made to possibly reduce the flow out time, it is still captivating to see what fraction of the patients LoS is used by the flow out time. The analysis shown in Table 29, shows that the on average 25% of the patients AAU LoS is taken up by outflow time. This percentage in itself is not worrying since the AAU serves as a buffer for the regular wards and facilitates planned admissions, hereby some extra flow out time is inevitable.

Although the fraction of time the outflow process takes, in relation to the AAU LoS, shows some new insight, it does not show for what type of patients the fraction is high. Therefore in Figure 34 the outflow time is plotted versus the AAU LoS. This table shows that several patients with a long AAU LoS, also had a long outflow time. Thus these patients stayed at the AAU, while their AAU LoS already could have ended. These patients stayed needlessly long at the AAU. There even seems to exist a positive correlation between the AAU LoS and the out flow time, though there are too many deviant observations for this relation to be statistically significant.

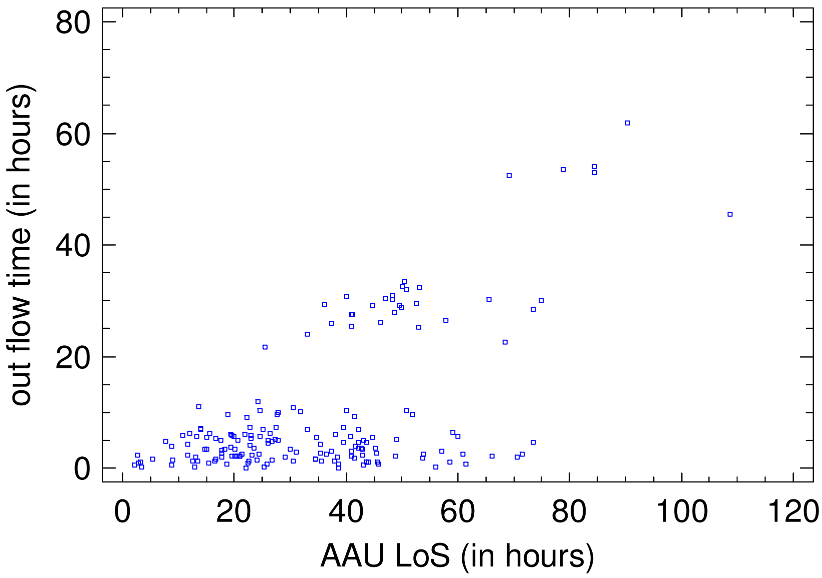


Figure 34: Plot of fraction of flow out time of patient's AAU LoS vs AAU Los

Table 29: Sample statistics of fraction of flow out time of patient's AAU LoS

Statistic	Value
Count	173
Average	0.26
Standard deviation	0.23
Coeff. of variation	89.22%
Minimum	0.00
Maximum	0.87
Range	0.87
Stnd. skewness	4.94
Stnd. kurtosis	-0.88

Appendix Y Comparison AAU LoS for surgery or no surgery

Mann-Whitney Test

Ranks

	SurgeryCode	N	Mean Rank	Sum of Ranks
AAU_LoS	No_Surgery	1384	796,54	1102406,50
	Surgery	222	846,91	188014,50
	Total	1606		

Test Statistics[a]

	AAU_LoS
Mann-Whitney U	143986,500
Wilcoxon W	1102406,500
Z	-1,502
Asymp. Sig. (2-tailed)	,133

a. Grouping Variable: SurgeryCode

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		AAU_LoS
Most Extreme Differences	Absolute	,071
	Positive	,071
	Negative	-,002
Kolmogorov-Smirnov Z		,985
Asymp. Sig. (2-tailed)		,287

a. Grouping Variable: SurgeryCode

Appendix Z Comparison AAU LoS for function or no function

Mann-Whitney Test

Ranks

	Function_code	N	Mean Rank	Sum of Ranks
AAU_LoS	No_function	1360	778,22	1058380,00
	Function	239	923,93	220820,00
	Total	1599		

Test Statistics[a]

	AAU_LoS
Mann-Whitney U	132900,000
Wilcoxon W	1058380,000
Z	-4,499
Asymp. Sig. (2-tailed)	,000

a. Grouping Variable: Function_code

Two-Sample Kolmogorov-Smirnov Test

Test Statistics[a]

		AAU_LoS
Most Extreme Differences	Absolute	,170
	Positive	,170
	Negative	-,003
Kolmogorov-Smirnov Z		2,427
Asymp. Sig. (2-tailed)		,000

a. Grouping Variable: Function_code

Appendix AA Inflow analysis for forecasting

Summary Statistics for inflow per week

Count	24
Average	128.833
Standard deviation	12.4679
Coeff. of variation	9.67757%
Minimum	103.0
Maximum	157.0
Range	54.0
Stnd. skewness	0.2732
Stnd. kurtosis	0.189262

Summary Statistics for inflow per day of the week

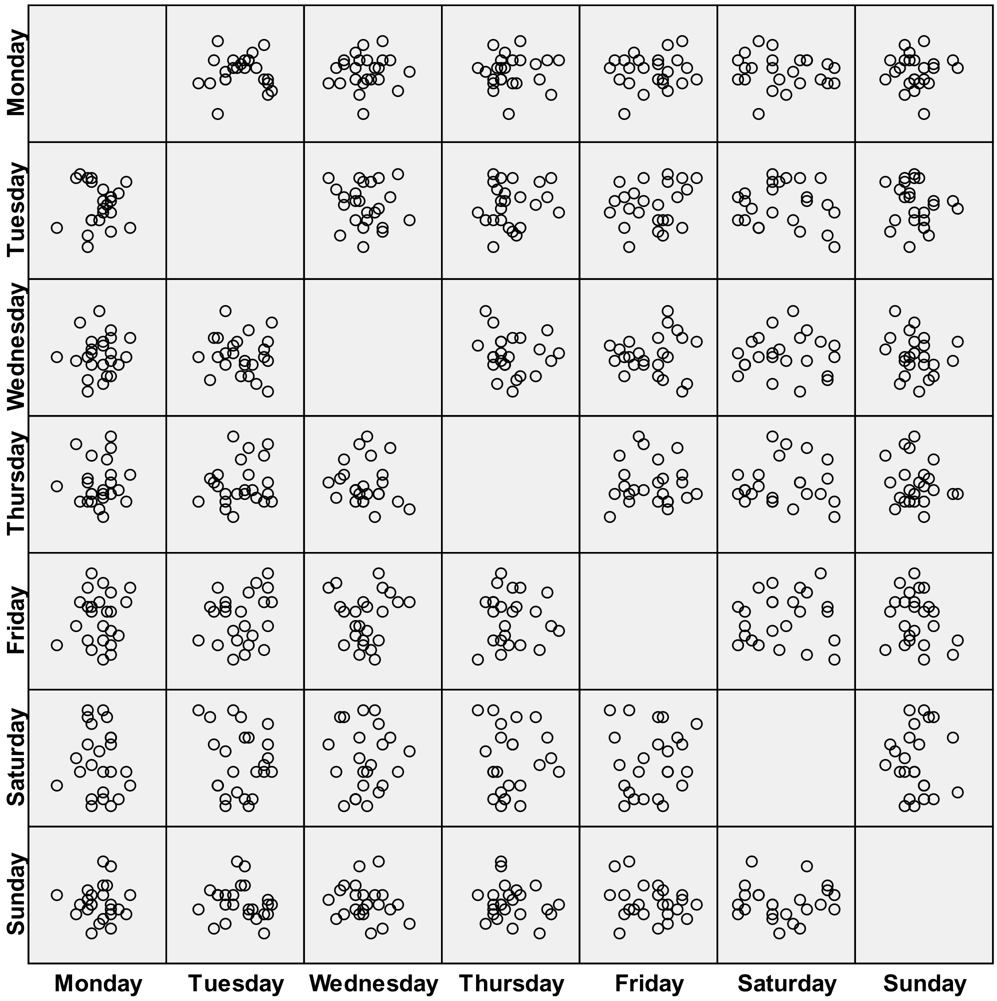
day	*Count*	*Average*	*Standard Deviation*	*Coefficient of variation*	*Minimum*	*Maximum*	*Range*	*Standardized Skewness*	*Standardized Kurtosis*
Monday	24	23.0833	4.25202	18.4203%	12.0	31.0	19.0	-0.940249	0.823491
Tuesday	24	18.9583	5.44122	28.7009%	8.0	27.0	19.0	-0.388567	-0.943703
Wednesday	24	20.5417	5.08176	24.7388%	11.0	32.0	21.0	0.492987	0.00179481
Thursday	24	17.6667	5.54559	31.3902%	9.0	30.0	21.0	1.65766	-0.0557063
Friday	24	20.6667	5.15555	24.9462%	12.0	30.0	18.0	-0.0219983	-1.09521
Saturday	24	14.5	4.64384	32.0265%	8.0	22.0	14.0	0.417733	-1.22014
Sunday	24	13.4167	3.61057	26.9111%	7.0	22.0	15.0	1.19609	0.658979
Total	168	18.4048	5.76302	31.3127%	7.0	32.0	25.0	0.814209	-2.1403

Summary Statistics for fraction inflow per day of the week

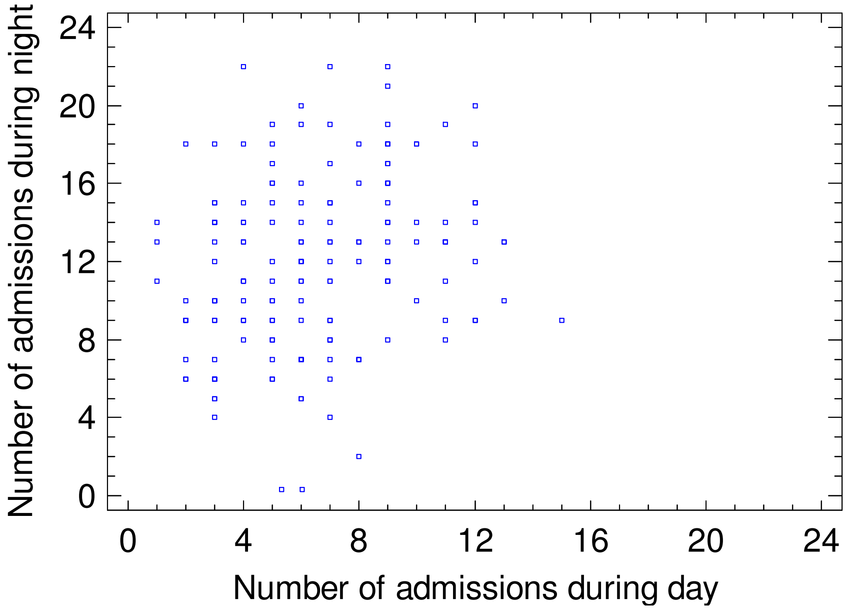
day	*Count*	*Average*	*Standard Deviation*	*Coefficient of variation*	*Minimum*	*Maximum*	*Range*	*Standardized Skewness*	*Standardized Kurtosis*
1	24	0.17941	0.0307112	17.1179%	0.116505	0.229508	0.113003	-0.757624	-0.367724
2	24	0.146529	0.0379972	25.9315%	0.0720721	0.19708	0.125008	-0.541178	-0.992942
3	24	0.159791	0.0372412	23.3061%	0.0827068	0.246154	0.163447	-0.0167823	0.309764
4	24	0.136732	0.0381622	27.9102%	0.0737705	0.217391	0.143621	1.00679	-0.352381
5	24	0.159953	0.0347296	21.7124%	0.0983607	0.224	0.125639	-0.313722	-0.814151
6	24	0.112465	0.0358608	31.8863%	0.0689655	0.198198	0.129233	1.61153	0.120323
7	24	0.105121	0.030052	28.588%	0.0546875	0.170543	0.115855	0.891189	-0.31663
Total	168	0.142857	0.0425193	29.7635%	0.0546875	0.246154	0.191466	0.209013	-2.31897

Summary Statistics for fraction: day / total inflow per day of the week

day	*Count*	*Average*	*Standard Deviation*	*Coefficient of variation*	*Minimum*	*Maximum*	*Range*	*Standardized Skewness*	*Standardized Kurtosis*
1	24	0.394501	0.123735	31.365%	0.0833333	0.625	0.541667	-1.01098	0.457503
2	24	0.315134	0.107507	34.1147%	0.0666667	0.545455	0.478788	-0.898893	0.934643
3	24	0.368877	0.128747	34.9024%	0.2	0.636364	0.436364	1.01875	-0.705112
4	24	0.353705	0.119245	33.713%	0.0714286	0.545455	0.474026	-0.443651	-0.0559758
5	24	0.36242	0.0958886	26.4579%	0.166667	0.578947	0.412281	-0.148937	0.546809
6	24	0.31877	0.103875	32.5863%	0.166667	0.466667	0.3	0.123358	-1.38248
7	24	0.326534	0.152495	46.701%	0.142857	0.8	0.657143	2.84356	2.61672
Total	168	0.348563	0.121032	34.723%	0.0666667	0.8	0.733333	1.65711	1.14071



Matrix scatterplot of the number of admissions per day of the week



Scatterplot of the number of night admissions versus the number of day admissions