Decreasing waiting time for mental health patients at Victoria hospital

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Industrial Engineering & Management
University of Twente

DECREASING WAITING TIME FOR MENTAL HEALTH PATIENTS AT VICTORIA HOSPITAL

Bachelor thesis

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PREFACE

The health care environment is a very complex one, and it is a very important sector for all of us. For this project I dove into the world of mental health care at the Victoria hospital in London, Ontario. Meeting the physicians, nurses, administrators, data analysts, from the hospital and mental health facilities outside the hospital was very interesting. I enjoyed working with everyone, and I am thankful for all the time and commitment everyone had for the project.

The project started out at the Emergency department but quickly shifted towards the Inpatient Psychiatry department. Getting a feel for the work that everyone does at both these departments and how a hospital operates was nice to experience. Being able to apply knowledge from my study Industrial Engineering and Management to systematically analyze the problem of waiting times for adult mental health patients was very satisfying.

I want to give my special thanks to David Stanford from the University of Western Ontario for the opportunity to carry out this study, and for the always enthusiastic help during the project. I want to thank my project partners Shenghao and Hongrui for the help with the project.

I also want to thank my supervisors from the University of Twente, Erwin Hans and Derya Demirtas for all the critical feedback and guidance on this report.

I hope you find the study helpful and enjoy reading this report.

Sjoerd Mesman
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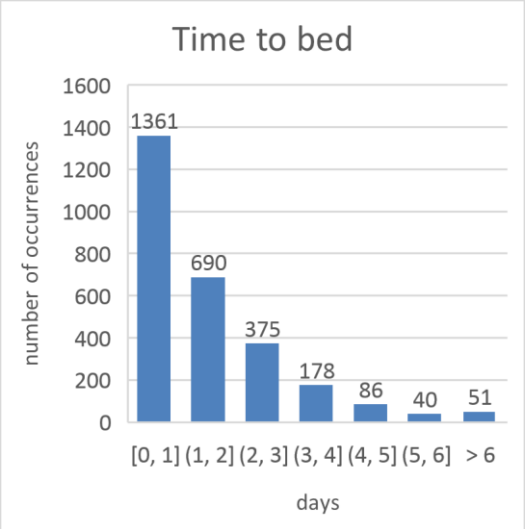
MANAGEMENT SUMMARY

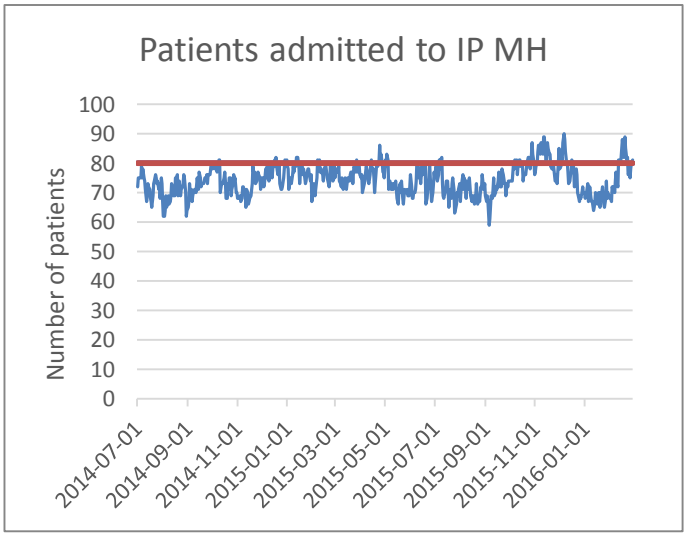
BACKGROUND

This report investigates the waiting time for adult mental health patients at the Victoria hospital in London, Ontario. The hospital is an acute care hospital, and it handles around 180 emergency patient arrivals per day, of which 7.2% are mental health patients. It also has an Inpatient Psychiatry department where adult mental health patients that need hospital admission stay and receive treatment.

PROBLEM DESCRIPTION

The mental health patients at Victoria hospital encounter significant waiting time, especially if they end up getting admitted to Inpatient Psychiatry. The Inpatient Psychiatry department operates at 93% bed utilization which is quite high for a department with inherently variable (non-elective) patient arrivals and length of stay. Patients often need to wait a long time before they can enter a bed at Inpatient Psychiatry: on average 1.5 days (90th percentile 3.5 days).





The lack of capacity in community support resources and at the Parkwood institute lead to more patient arrivals, and more long-term stay patients at Inpatient Psychiatry. Because of this additional workload the beds are often full, which means patients are waiting for a bed while in the Emergency department, which decreases the capacity there.

The impact of the quite extreme long length of stay of ALC patients leads to substantial use of bed capacity that cannot be used to help other patients. In a one-year period from 2015 – 2016, 10% of the bed days were used by ALC patients.

OBJECTIVE

In the current situation the waiting time for adult mental health patients at Victoria is quite high, especially the time to bed when a patient is admitted to Inpatient Psychiatry. The objective of this study is to identify interventions that decrease the waiting times for adult mental health patients at Victoria hospital.

Approach

In order to determine how to decrease the waiting time for adult mental health patients the current system is evaluated. The pattern of patient admissions and the length of their stay at Inpatient Psychiatry is analyzed, and based on the characteristics we develop a discrete event simulation model. Because of the high time to bed the scope of the model is the Inpatient Psychiatry department, starting with admission, until discharge.

Based on the analysis of the current system, interviews with hospital staff, and similar case studies from literature we propose four interventions to decrease the waiting time. The estimated impact of these interventions is evaluated with the developed computer simulation model.

Results

The main factors that contribute to the waiting time of mental health patients are: the number of patient admissions to Inpatient Psychiatry, for how long the patients stay at the ward, and the number of patients that can be helped (admitted) simultaneously. The fact that these factors influence the waiting time is expected, however the impact that even relatively small changes have on the waiting time is surprising.

Even a 1% or 2% decrease in the number of patient admissions to Inpatient Psychiatry is expected to decrease the average time to bed by approximately 6 – 10 hours. Decreasing the time patients spend at the ward by 1% or 2% has a similar impact. The impact of ALC patients on the capacity of Inpatient Psychiatry is substantial. Significant decreases in waiting time are achieved if patients would never stay for longer than 300, 200, or 100 days. If no patients would stay for longer than 100 days, the average time to bed is expected to decrease by approximately 90%. If the number of patient admissions or the length of their stay at the ward cannot be decreased, a third option exists. The waiting time is also reduced by adding additional beds, but it is a very expensive option.

Conclusion & outlook

Even small reductions of the number of patient admissions or the time they stay at Inpatient Psychiatry will decrease the 'time to bed', and reduce overall waiting time. Never having patients stay for more than 100 days is estimated to lead to an approximate 90% reduction of waiting time for adult mental health patients, so reduction of ALC days is a high priority.

However, at a system level more resources might be needed outside Victoria hospital in order to further reduce ALC days. Esensoy & Carter (2015) have created a quantitative model to look at patient flow at the LHIN level. Performing such a study to analyze the bigger picture might be useful to identify the bottlenecks in the system and get support to fix those problems.

Performing a more detailed study on the Inpatient Psychiatry department might identify (administrative) inefficiencies. The patient can stay for shorter times while also remaining or improving in quality of care if such improvements are identified. Important is to carry out such an analysis with regards to quality of care.

Another area of interest is the waiting time and length of stay for regular mental health patients and PICU patients at Inpatient Psychiatry. In interviews staff indicated mental health patients that need a PICU bed at Inpatient Psychiatry need to wait for longer than regular patients. No data is currently retained on the waiting times and length of stay split over PICU or regular patients.

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GLOSSARY

Abbr.	Full-out	Definition
IP	inpatient	A patient who stays for at least one night.
OP	outpatient	A patient who does not stay overnight.
ED	Emergency Department	The unit of a hospital in which acute, severe, or urgent illnesses and/or injuries are treated.
IP MH	Inpatient Mental Health	Used in this report as a shorthand for the Inpatient Psychiatry department
PICB	Psychiatric Intensive Care Bed	A bed with higher staffing intensity and a safe environment (e.g. no sharp objects) for patients that require more intensive care and/or are a danger to themselves or others.
PICU (bed)	Psychiatric Intensive Care Unit (bed)	Commonly used in the Inpatient Psychiatry department to refer to PICB beds. Not to be confused with the Intensive Care department.
CEPS	Centralized Emergency Psychiatry Services	A team consisting of nurse case managers, psychiatrists, and residents who conduct assessments of mental health patients.
ALC (patient)	Alternative Level [of] Care	A term used to describe a patient whose treatment is done, but cannot be discharged from the hospital, usually because of lack of capacity in community support.
	ED boarding	A patient is boarded in the ED if the patient is admitted to an IP unit and the IP does not have a bed available in which to place the patient.

1 INTRODUCTION

1.1 THE RESEARCH PROJECT

In the last few years Victoria hospital in London, Ontario has been struggling to deal with the amount of mental health patients needing care. The adult mental health inpatient beds have been consistently filled up, resulting in admitted mental health patients needing to wait in the emergency department for a bed to become available at the inpatient ward.

The consistently high bed occupancy at Inpatient Psychiatry results in high waiting times before patients can enter. The patients wait inside the emergency department which leads to bed blocking (so less capacity available in the ED), unpleasant experiences for both mental health patients and other patients residing in the emergency department as a result. A local newspaper has even written articles on the subject.

The goal for the research project is to identify and assess possible interventions that can be made to decrease the waiting time for mental health patients at Victoria hospital.

The layout of this chapter is as follows: Section 1.2 gives a definition of 'mental illness'. Section 1.3 introduces the hospital and the departments involved. Section 1.4 introduces the Parkwood institute, and Section 1.5 discusses 'community support', both provide care for mental health patients. Section 1.6 briefly discusses who is involved with this research project. Section 1.7 discusses the research objective and research questions.

1.2 MENTAL ILLNESS DEFINITION

To give a better idea of what a mental illness is, the definition referenced by MedlinePlus is helpful:

"Mental illness refers to a wide range of mental health conditions — disorders that affect your mood, thinking and behavior. Examples of mental illness include depression, anxiety disorders, schizophrenia, eating disorders and addictive behaviors.

Many people have mental health concerns from time to time. But a mental health concern becomes a mental illness when ongoing signs and symptoms cause frequent stress and affect your ability to function in your daily life. In most cases, symptoms can be managed with a combination of medications and talk therapy (psychotherapy). Signs and symptoms of mental illness can vary, depending on the disorder, circumstances and other factors."

("Mental illness - Mayo Clinic," n.d.)

As defined above, mental illness refers to a wide range mental health conditions. The following three sections discuss the care 'range' that different organizations in London provide for mental health patients.

1.3 VICTORIA HOSPITAL RESEARCH CONTEXT

Victoria Hospital is an acute care hospital located in London, Ontario. The emergency department handles approximately 180 patient arrivals per day. The emergency department has a capacity of 42 beds, but not all beds are available for use by all patient types. 8 out of the 42 beds are Mental Health rooms, which are intended for mental health patients.

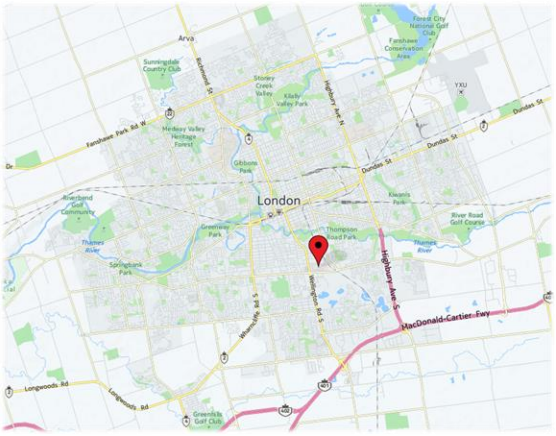

Figure 1.1 – Location of Victoria hospital in London

Figure 1.2 – Victoria hospital

As seen in Section 1.2, 'mental illness' encompasses a wide range of conditions. Victoria hospital provides the following services:

"Victoria hospital offers mental health services for adults with a serious mental illness: time-limited mental health assessments and treatment, crisis intervention and stabilization. They provide one-on-one and group services and coordinate with community resources for follow-up treatment and community support provided as part of discharge planning." ("Victoria Hospital - Adult Mental Health Care Program," n.d.)

If a patient goes to the Victoria hospital emergency department (ED) and during assessment it becomes clear the patient needs to be admitted, they get transferred to Inpatient Psychiatry. The Inpatient Psychiatry department houses 62 regular beds, 12 PICU (Psychiatric Intensive Care Unit) beds, and 6 surge beds. The 6 surge beds are the same as regular beds, the only difference is that they were originally meant to deal with spikes in inpatient admissions. Currently all 80 beds on Inpatient Psychiatry are consistently in use.

Patients waiting for an Inpatient Psychiatry bed wait in the ED. It occurs regularly that more than 8 mental health patients are present in the ED, a significant portion of those are patients waiting for an inpatient bed.

A significant number of inpatient beds are typically used by Alternative Level of Care (ALC) patients. In this context ALC patients are patients ready to be discharged, but the hospital has no place to discharge these patients to. The mean length of stay at Inpatient Psychiatry for ALC patients is 104 days, compared to 16.4 days for non-ALC patients.

Victoria hospital is part of LHSC (London Health Science Center) organization, which also contains the University Hospital and the Children's hospital, all located in London.

1.4 PARKWOOD INSTITUTE

The Parkwood institute (or 'Parkwood' for short) is also in London, which is designed to deal with Mental Health patients that need to be admitted to a hospital for a longer amount of time.

Parkwood does not have an Emergency Department. If assessment of a patient at Victoria hospital emergency department reveals a patient needs a long admission to Inpatient Psychiatry, then the patient should be referred from Victoria hospital to the Parkwood institute. Parkwood often does not accept these referrals because they are full.

The Parkwood institute is not part of LHSC, but rather of St. Joseph's Healthcare London (SJHC). Both the SJHC and LHSC are part of the South West Local Health Integration Network.

Figure 1.1 - Local Health Integration Networks in Ontario

1.5 COMMUNITY SUPPORT FOR MENTAL HEALTH IN LONDON

In addition to the hospitals, many organizations offer some service or treatment for mental health patients in London, which we will refer to as 'community support'. One example is homeless shelters. From the view of Victoria Hospital these community support resources are needed to allow the hospital to only deal with the acute issues of mental health patients, leaving the sub-acute problems to community support, enabling the hospital to see more acute mental health patients.

There are many services, but not all might be easy to find. Some patients who go to the ED might not need to go to the ED, but simply do not know where else to go. The newly opened 24/7 Walk-In Crisis Center can help patients connect to the right resource in the community or at the hospital, and could potentially decrease the amount of unnecessary arrivals to the Victoria hospital emergency department.

Funding for these community services is somewhat unreliable as the provincial government policies on what programs they support change regularly (Interview with Walk-In Crisis Centre, May 6th 2016). The lack of stable funding, and/or lack of resources in general lead to shortages in community resources.

1.6 Overview of stakeholders & people involved

As discussed in the previous sections, the Emergency Department and Inpatient Psychiatry experience problems because of the full system and as such are important stakeholders. Obvious other stakeholders are the patients themselves, who would benefit from lower waiting times.

In any project regarding change it is helpful to determine the 'problem owner', the person who is affected negatively by current problems in some way (so there is motivation for change) and also has power within the organization to improve the situation. In the case of this project that is the Site Chief of Psychiatry at Victoria.

Additionally, a few psychiatrists from Inpatient Psychiatry, as well as a number of physicians, Centralized Emergency Physician Services (CEPS) nurses, and a research coordinator from the emergency department have been involved with the project.

Finally, a member of the Complex Transition Team that helps with finding a place for (ALC) patients in difficult cases was involved as well.

1.7 Research objective and questions

In summary: patients that have acute mental health issues and turn to Victoria hospital for help have high wait times. The high bed occupancy at Inpatient Psychiatry leads to beds occupied in the Emergency department by patients waiting for a bed at Inpatient Psychiatry, which in turn leads to crowding at the Emergency department. On occasion this might contribute to a full ED, increasing the wait time for all patients.

This project focuses on the adult mental health services at Victoria hospital, the Child & Adolescent inpatient unit operates completely separate and thus is out of scope.

1.7.1 Research objective

The high wait times for adult mental health patients lead to problems for the patient, impacting the patient, the Inpatient Psychiatry staff as well as patients and staff at the Emergency department.

The research objective is to:

Identify interventions that decrease the waiting times for adult mental health patients at Victoria hospital

1.7.2 Research questions

To help achieve the research objective the following research questions are explored:

1. What type of care is required by adult mental health patients at Victoria hospital?

Before understanding the system of care and the way services are laid out at Victoria, it is useful to understand the different kind of services mental health patients need. Section 2.1 discusses this.

2. What does the patient pathway for adult mental health patients at Victoria look like?

In order to improve the waiting time of mental health patients, the way the current system operates must be clear. In Section 2.2 discusses the departments involved and the way the patient flows through the system.

3. What is the current performance of Victoria hospital regarding adult mental health patients?
    a. What performance measures should be evaluated?
    b. What is the current performance of the Emergency department?
    c. What is the current performance of Inpatient Psychiatry?

Before attempting to fix a problem, verification should be done to make sure the problem exists, and an overview of different performance measures helps in understanding the current system performance. Section 2.3.1 discusses what performance measures are appropriate to evaluate, Section 2.3.2 discusses the current performance of the Emergency department, Section 2.3.3 discusses the current Inpatient Psychiatry performance. Section 2.3.4 summarizes the results.

4. What are the main factors that influence waiting time for adult mental health patients at Victoria?

Often problems do not exist in a vacuum but are linked to other problems. In order to get a clear overview of the problems related to waiting time for adult mental health patients at Victoria, we present a problem cluster in Section 2.4, listing related problems and their relationships. We use the problem cluster to identify the root problem(s) to focus on.

5. What methods of analyzing delays in healthcare are described in the literature?

Chapter 3 discusses the methods applied in the literature to study delays in healthcare, and which of those methods is most suitable to apply to this project.

6. What are interesting scenarios and interventions to evaluate, related to the waiting time for adult mental health patients at Victoria hospital?

Chapter 0 discusses the scenarios and interventions that are of interest to study and estimate the effect of their implementation on the waiting time.

7. What are the expected effects of the chosen scenarios and interventions on the waiting time for adult mental health patients at Victoria hospital?

The type of analytical model to use, and the tests and verification of that choice are described in Chapter 5. The model is then applied to calculate the expected effects of scenarios and interventions, the results are discussed in Chapter 6.

Finally the conclusion of the report is discussed in Chapter 7.

2 CURRENT SYSTEM

This chapter describes the current system in detail. Section 2.1 briefly gives an overview of the type of care required by mental health patients at Victoria. Section 2.2 describes the patient pathway and relevant departments for adult mental health patients. Section 2.3 then discusses the current performance of those departments. Section 2.4 discusses the problem cluster which shows the relevant problems and their relationships, useful for identifying the most important problems.

2.1 TYPE OF CARE REQUIRED BY MENTAL HEALTH PATIENTS

As described in Section 1.2, a wide range of mental health conditions with varying severity exist. Some patients can be served well by their general practitioner or by one of the many community support services. Other patients are served best with one or multiple outpatient visits with psychiatrists at for example Victoria. Patients with a more severe condition might need inpatient admission. Patients that need long stay admission should be served by Parkwood.

This project focuses on adult mental health patients visiting the ED or Inpatient Psychiatry at Victoria hospital.

2.2 DEPARTMENTS INVOLVED

2.2.1 CONCISE PATIENT FLOW

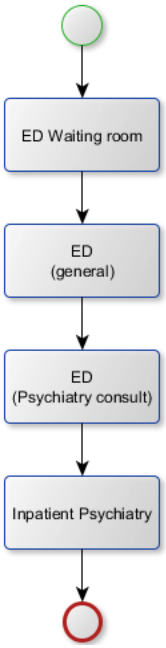

Figure 2.1 Concise patient flow

A mental health patient that gets admitted to Inpatient Psychiatry typically goes through the 4 'steps' shown in figure 2.1:

1) Arrive to the waiting room of the Emergency Department
2) General evaluation of patient by ED doctor
3) Evaluation by Psychiatric team (CEPS)
4) Admission into Inpatient Psychiatry

Some patients do not pass through the waiting room (e.g. if they arrive via ambulance). In addition, not all patients that show up to the hospital are admitted to Inpatient Psychiatry. In the following sections the relevant departments and the patient pathway(s) are explained in more detail.

2.2.2 *EMERGENCY DEPARTMENT*

As seen in figure 2.1, a mental health patient goes through the following 3 steps in the Emergency Department: **ED waiting room**, **ED (general)**, and **ED (Psychiatry consult)**.

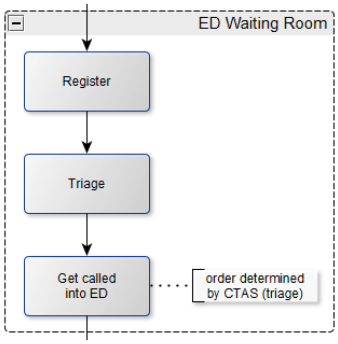

Figure 2.2 - ED Waiting Room

In the waiting room the patient registers at the desk. Next step is triage where the urgency of the patient to get treatment is judged, and the patient is given a Canadian Triage and Acuity Scale (CTAS) score between 1 (most urgent) and 5 (least urgent).

Patients get called into the Emergency Department based on their CTAS score (highest urgency first) whenever a spot becomes available. Some patients might decide to leave before getting called into the ED (e.g. if they have been waiting a long time), but based on interviews this appears to be insignificant for mental health patients at Victoria.

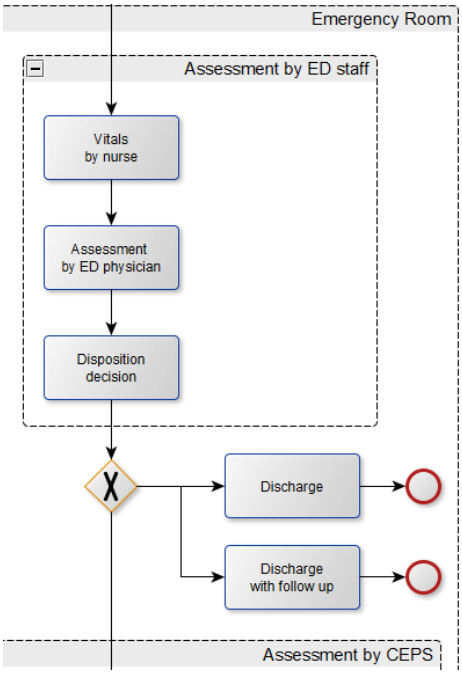

Figure 2.3 - ED (general)

Once a patient is called into the Emergency Room, the generic assessment takes place. A nurse checks the vitals of the patient, and the ED Physician evaluates the patient to determine a treatment plan. With Mental Health patients three choices are possible:

- **Discharge** – discharge the patient
- **Discharge with follow up** – discharge but arrange some sort of follow up (e.g. a telephone consult with a psychiatrist)
- **Order a CEPS consult** – order a consult by the Psychiatry team in the ED

The ED Physician cannot directly admit patients to Inpatient Psychiatry, but if he/she suspects the patient needs to be admitted, a consult can be ordered with Centralized Emergency Psychiatry Services (CEPS). The CEPS team is experienced in the field of Psychiatry and can decide if the patient needs to be admitted.

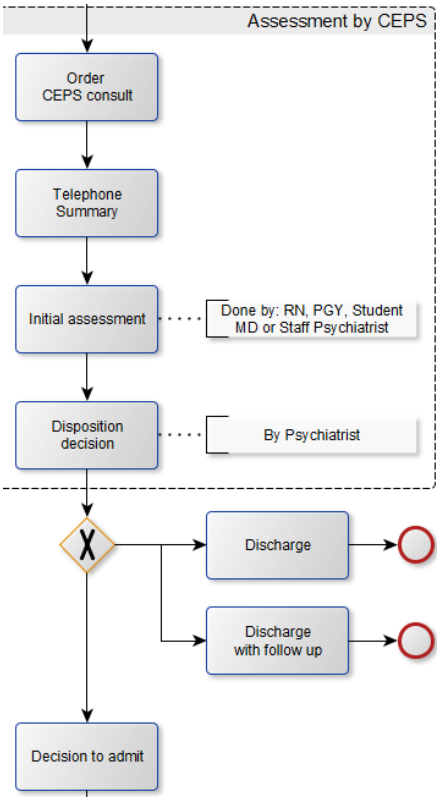

Figure 2.4 - ED (Psychiatry consult)

The ED physician orders the CEPS consult, and when somebody on the CEPS team is available they briefly talk about the patient over the phone.

After the telephone summary the patient is put on the list of CEPS, and someone from CEPS comes to do the initial assessment, which can be done by any member of the CEPS team.

The disposition decision can only be made by a Psychiatrist (so not by a nurse, resident or student doctor). Again the choices are to **Discharge**, **Discharge with follow-up**, or make the **Decision to admit**.

In some cases, the CEPS team might determine a patient's condition might be less severe than the ED physician thought, and discharge with a follow-up telephone consult is sufficient for that patient.

In case the patient needs to be admitted the CEPS Psychiatrist needs to determine if the person should be admitted to Victoria or should be transferred to another hospital (e.g. Parkwood if long term hospital care is necessary), or to Inpatient Psychiatry at Victoria.

At Victoria the patient can be admitted to a regular bed or a Psychiatric Intensive Care Bed (PICB, also called PICU). If a patient is a significant danger to himself or others he/she can be admitted to a PICU bed with more intensive support and a more suitable room (e.g. no sharp objects).

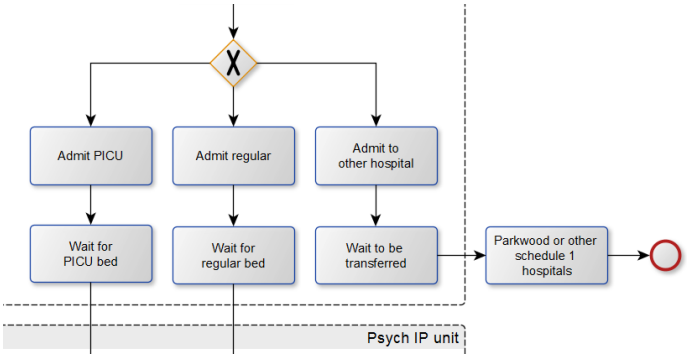

Figure 2.5 - ED admit choices

After admission the patient waits in the Emergency Department until a bed becomes available at Inpatient Psychiatry, and then gets transferred.

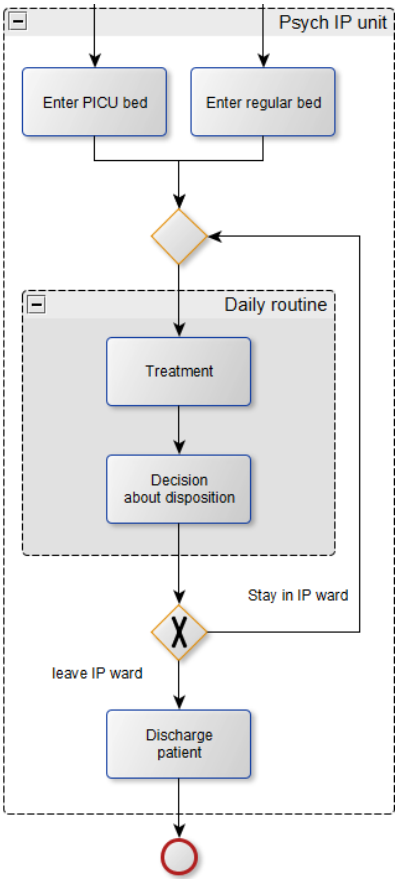

Figure 2.6
Inpatient Psychiatry flow

2.2.3 *Inpatient Psychiatry*

Once the patient is transferred to Inpatient Psychiatry treatment is done with (nearly) daily routine. Treatment can be done in many different ways, depending on the specific needs of a patient. The patients at Inpatient Psychiatry are treated by teams handling between 6 and 12 patients, making sure changes to the treatment plan are made when necessary. The patient is monitored and once the Psychiatrist responsible feels the patient is ready, the patient can be discharged from Victoria.

Patients do not necessarily stay in the type of bed during their stay in the ward. In some cases, patients that originally get admitted to a PICU bed can improve and get relocated to a regular bed, or the other way around. No electronic record is kept of these switches.

In some cases, the patient is ready to be discharged but there is no place for the patient to go (e.g. no spots available in a nursing home, or at the homeless shelter). In that case the hospital cannot discharge the patient and has to keep them in a bed (and continue treatment where needed).

These cases can be considered 'bed block', since the patient treatment is finished but he or she is still occupying a bed, which means no new patient can start treatment at Inpatient Psychiatry.

2.2.4 *Other departments involved*

In addition to the **Emergency Department** and **Inpatient Psychiatry**, the other department that is occasionally involved is **Medicine**. Some mental health patients also have physical problems that need treatment (especially elderly mental health patients).

Hospital policy is patients should be physically cleared (meaning they have no physical problems that need treatment) before admission to Inpatient Psychiatry, so the patient might need to be sent to the Medicine department, before continuing treatment at Inpatient Psychiatry.

The other department patients might be sent to is **Intensive Care**, however this is very rare. Once the patient is no longer in life-threatening situation he or she might be discharged from the hospital, or admitted to Inpatient Psychiatry (through CEPS consult) depending on the case.

2.3 CURRENT SYSTEM PERFORMANCE

Now that the Emergency department and Inpatient Psychiatry department have been identified as the relevant departments for adult mental health care, a better overview of how they are performing is needed. Knowing for example where patients are waiting the longest, or how many patients are waiting to get into a department can be useful to identify the core problems.

Section 2.3.1 discusses what performance measures we evaluate, Section 2.3.2 evaluates the Emergency department performance, and Section 2.3.3 discusses the Inpatient Psychiatry performance regarding mental health wait times. Section 2.3.4 briefly summarize the results.

2.3.1 PERFORMANCE MEASURES

Before system performance can be described, a choice needs to be made on what indicators to use. Since the research focus is on waiting time for mental health patients the performance measures we choose are related to waiting time. The focus is on the Emergency department and Inpatient Psychiatry, and the aim of this Section is to determine how well the system is currently running.

In general, time spent waiting at a department, overall time spent at a department and the number of beds in use are of interest. Based on the data that is available the following measures can be evaluated at the departments:

Emergency department

- **ED Length of Stay** – time between ED registration and time patient leaves the ED

This is the total time a patient spends in the waiting room and inside the ED combined. Comparing how long a mental health patient stays in the ED compared to other patients is useful to check if something is different.

- **Initial wait** – time between ED registration and ED Physician Initial Assessment (PIA)

This indicates time patients wait from the moment of registration at the ED desk, until the initial assessment by an ED physician.

- **Time to CEPS consult** - time between requesting a consult and the arrival

If an ED physician thinks a patient needs to be admitted to Inpatient Psychiatry, Centralized Emergency Psychiatric Services (CEPS) needs to be consulted, and they can admit the patient if needed. The physician requests the consult, and it might take some time before the CEPS member arrives. This is time spent waiting by the patient.

- **Time to bed** – time an admitted mental health patient waits for a bed at Inpatient Psychiatry (ED disposition time to the time the patient left the ED)

Time to bed indicates a patient is done at the ED, and is waiting for a bed to become available at Inpatient Psychiatry. This also indicates how much capacity is being taken up in the ED because of bed unavailability at Inpatient Psychiatry.

- **Average queue length** (time to bed) – indicates the amount of beds occupied in the ED by patients waiting to get into Inpatient Psychiatry

Similar to the previous measure, and indicates how many ED beds are typically occupied by bed unavailability at Inpatient Psychiatry.

- **Chance of more than 8 MH patients in the ED** – since the ED has 8 MH rooms, knowing what percentage of time those beds would be insufficient is useful as an indicator of undesired queue length

Knowing what percentage of time the number of mental health patients in the ED is higher than 8 is useful to look at in addition to the average number of mental health patients waiting, to give a more complete picture.

Inpatient Psychiatry

- **Service time** – we consider the entire time a patient is physically in Inpatient Psychiatry as service time

The service time of Inpatient Psychiatry indicates how many days a patient typically receives care before being discharged. Together with the number of patients admitted per day it indicates how much 'work' the department should be able to handle per day.

- **Concurrent number of admitted patients** – the number of concurrent patients at IP MH over time

The number of concurrent admitted patients shows the bed utilization of IP MH, this is useful to confirm if the number of beds might be the issue or if enough beds are available.

- **Alternative Level of Care (ALC) percentage** – the percentage of ALC patients, and the percentage of bed days by ALC patients

Alternative Level of Care patients are (in virtually all cases) patients ready to be discharged, however unavailability of downstream resources (e.g. place in nursing home, or lack of housing) means the patient cannot be discharged and needs to wait in an Inpatient Psychiatry bed. The impact this has on the number of patients Inpatient Psychiatry can serve is very useful to assess.

All these measures combined should give a good idea of how long a mental health patient stays in the hospital, and what the waiting times look like currently.

2.3.2 Current Emergency Department performance

The Emergency department handles approximately 180 patient arrivals per day, 7.2% of those patients were labeled as Mental Health patient which means on average 13 mental health patient arrivals per day.

ED length of stay

The mean length of stay (LOS) in the ED for all patients is 6.6 hours (6 hours 35 minutes), compared to 20.2 hours (20 hours 11 minutes) for patients flagged as mental health patients. The following measures might explain the longer length of stay by mental health patients.

Initial wait

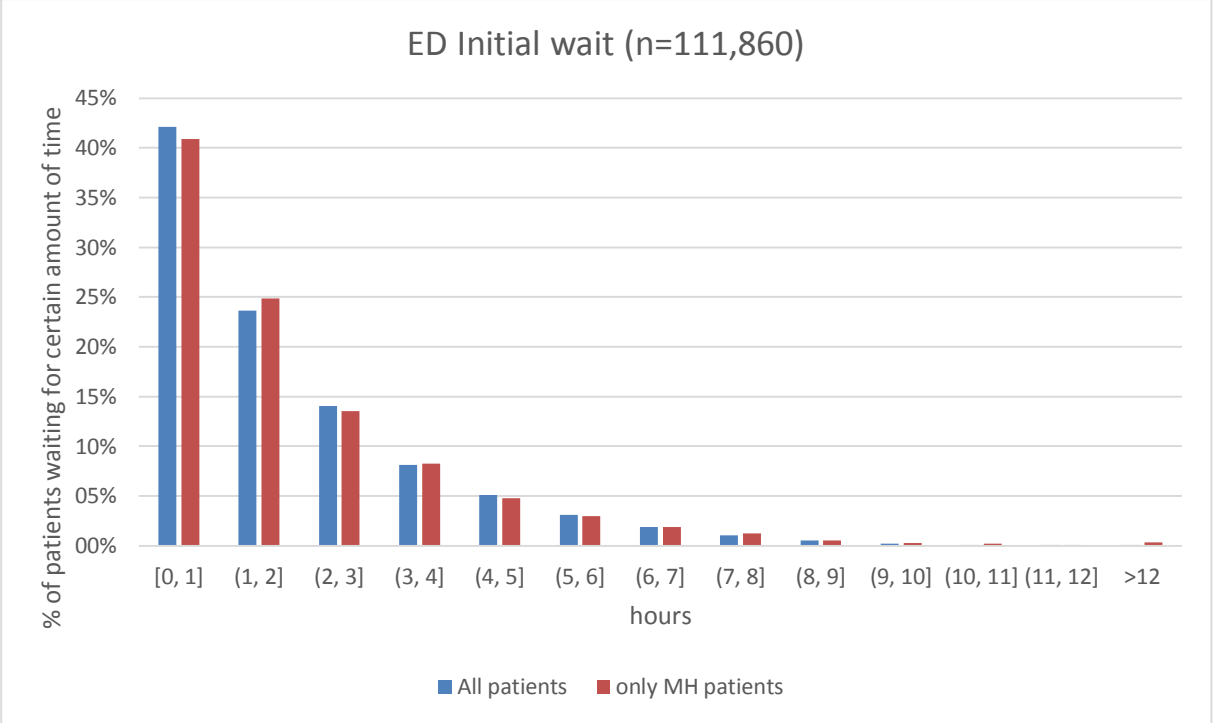

Figure 2.7 – Initial wait: registration until Physician Initial Assessment in the ED (Victoria hospital, 2014-2016, n=110860)

The initial wait is the time a patient is waiting starting at registration until the Physician Initial Assessment (PIA). As can be seen in Figure 2.7, it does not make a difference if the patient is a mental health patient or not for the initial waiting time. The initial waiting time has a mean of 1.85 hours (1 hour and 51 minutes).

Time to CEPS consult

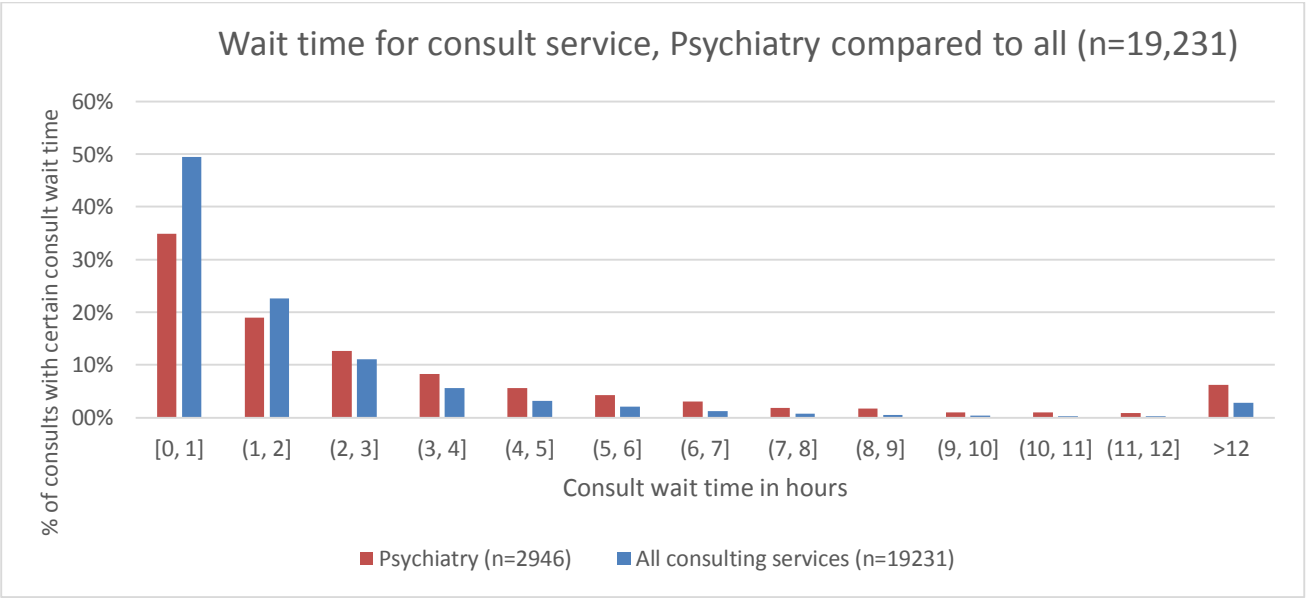

Figure 2.8 – Wait for Psychiatry consult: time from request to arrival of Psychiatry consult (Victoria hospital, 2014-2016, n=19231)

The time between a request for a psychiatry consult and the consult arriving is on average 3 hours and 49 minutes, and 90% of consults arrive in 8 hours and 20 minutes after request. Compared to all consult services: average of 2 hours and 13 minutes, and 90% of consults arrive in 4 hours and 21 minutes.

Psychiatry consults take longer to arrive, on average 1.5 hours longer, and longer consult wait times occur more often, with a big difference in the 90th percentile of Psychiatry consult wait times compared with all consulting services.

Time to bed

'Time to bed' indicates how long a patient needs to wait in the ED from the moment the decision to admit to Inpatient Psychiatry is made (ED disposition) to the moment the patient can be transferred. The mean time to bed for admitted mental health patients is 1.51 days, and the 90th percentile is a time to bed of 3.51 days. See Figure 2.9 for a histogram of the time to bed measure.

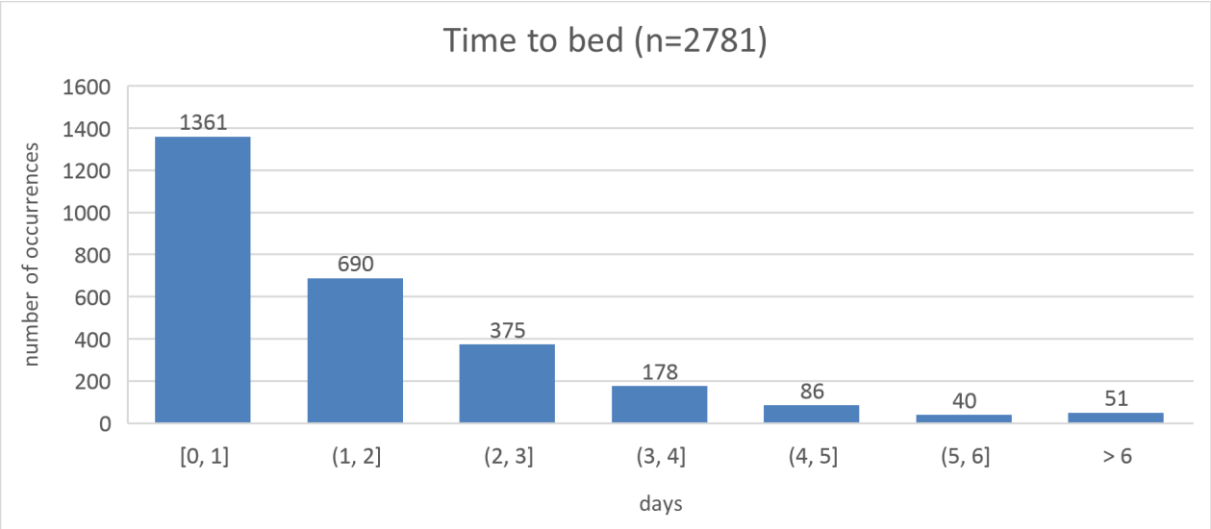

Figure 2.9 – Time to bed; time from ED disposition to ED left (Victoria hospital, 2014-2016, n=2781)

This is quite a long time for patients to waiting, after admission to IP MH patients wait on average a day and a half for a bed at Inpatient Psychiatry.

Average queue length

The 'Time to bed' measure indicates how many days an individual patient might be at the Emergency department waiting for an IP MH bed, but the average number of patients waiting is also of interest to get a better idea what capacity is used by patients waiting for a bed.

To calculate the number beds used, the time of day the measurement (census) is taken has a big impact, especially for the Emergency department since the number of patient arrivals per hour of the day changes significantly (true for all patient types, as well as only mental health patients). See Figure 2.10 for the impact a certain census time has on the results. The first 3 months of data are taken as warmup period and are ignored in the calculations.

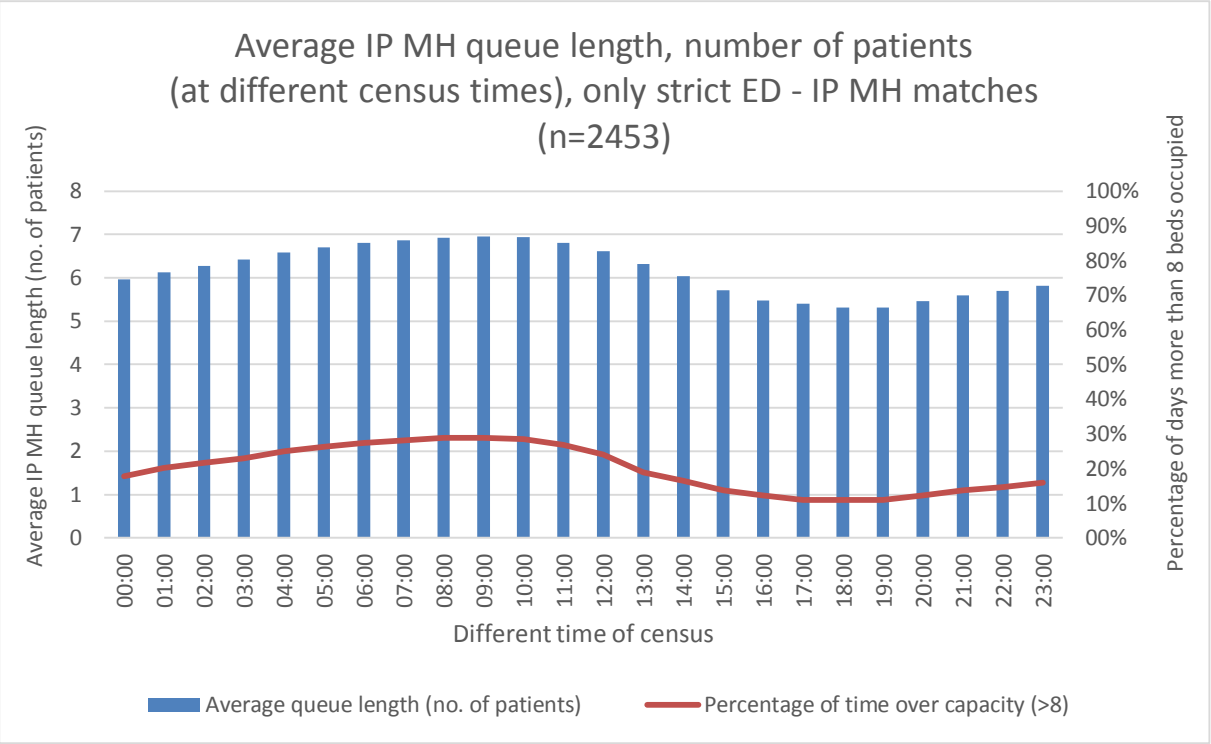

Figure 2.10 – Average number of patients waiting for a IP MH bed (Victoria hospital, 2014-2016, n=2453)

Taking the average over all census times (from midnight 00:00 to late evening 23:00) gives the following results: On average 6.17 patients admitted to Inpatient Psychiatry are waiting for a bed in the ED, and 19.9% of the time more than 8 admitted IP MH patients are waiting in the ED.

Chance more than eight mental health patients in ED

When all mental health patients present in the ED are taken into account (not only those that are admitted to IP MH) the results are as seen in Figure 2.11:

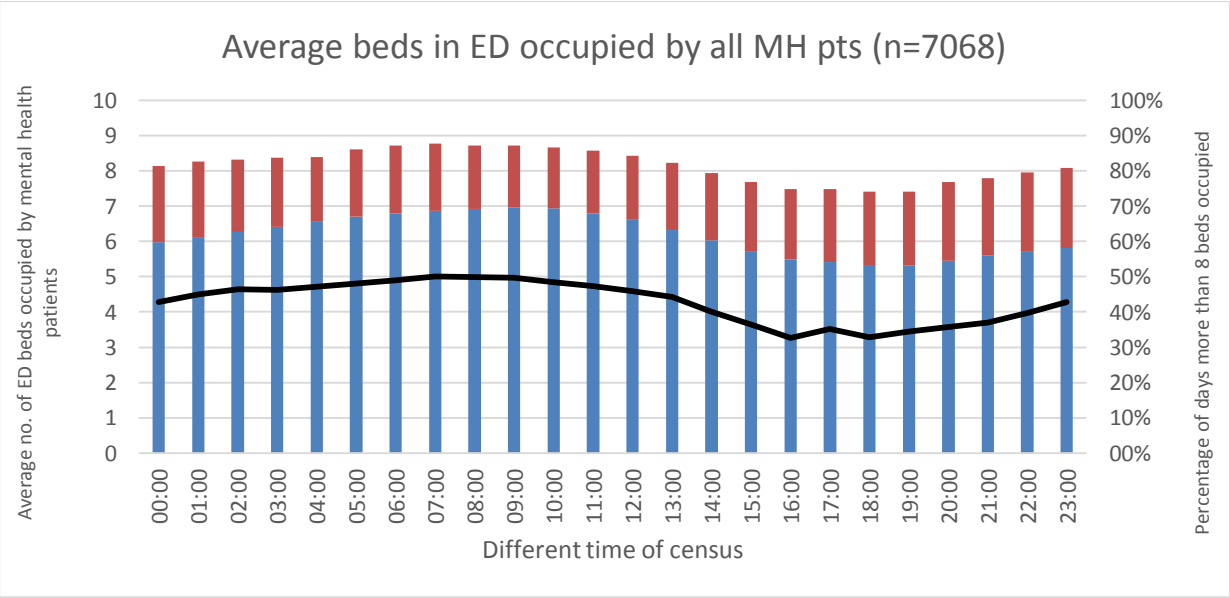

Figure 2.11 – Average number of beds occupied by all mental health patients (IP admitted waiting for bed + 'only-ED' MH patients, Victoria hospital 2014-2016, n=7068)

In Figure 2.11 the *blue* portion of the bar represents the average number of patients waiting for an IP MH bed, the *red* portion of the bar represents the average number of 'Only ED' mental health patients present that will not get admitted to Inpatient Psychiatry. The number of 'Only ED' patients present might be a little underestimated but should give a reasonable indication none the less.

On average 8.16 mental health patients are present in the ED, and 43% of the time more than 8 ED beds are occupied by mental health patients. See Appendix D for a day-by-day graph of the number of mental health patients in the ED over July 2014 to February 2016, including a 12-week moving average.

The number of 'Only-ED' patients could be an underestimate, however the estimate of the number of admitted IP MH patients should be quite accurate. It is clear from this overview that patients admitted to Inpatient Psychiatry and waiting for a bed consistently occupy a significant number of beds at the Emergency department.

2.3.3 *Current Inpatient Psychiatry performance*

The 'Time to bed' and 'Average queue length' of the previous section say a lot about the performance of Inpatient Psychiatry, a few additional measures in this section add additional insight.

Service time

An important measure is how many days a patient spends at the ward, since this indicates how much time or bed days are typically needed for a patient.

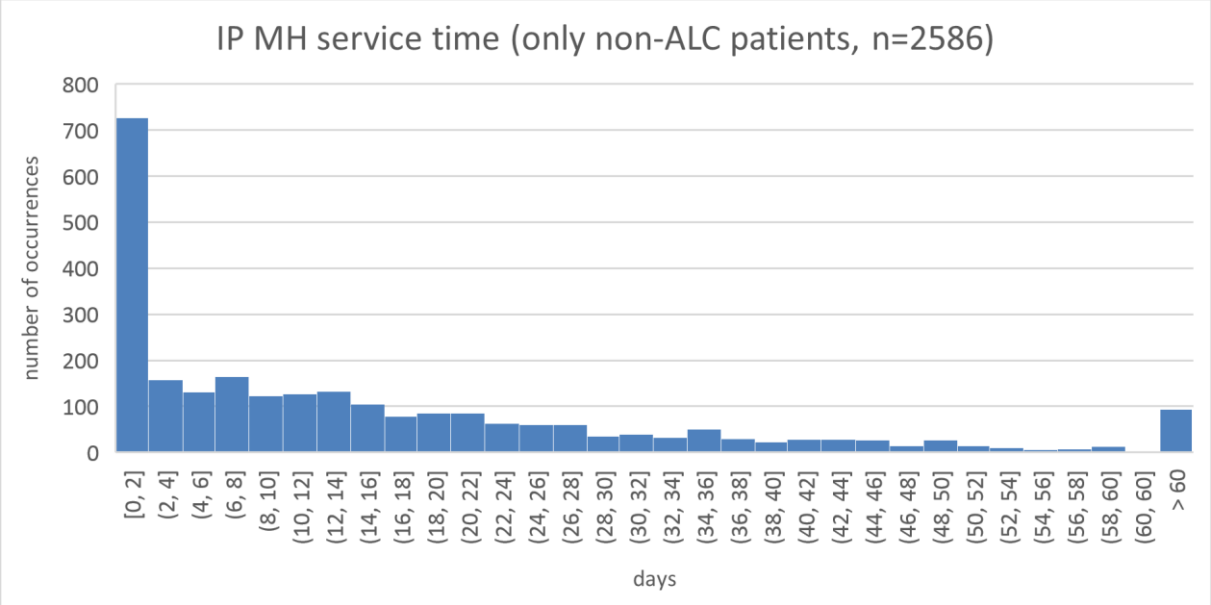

Figure 2.12 – Inpatient Psychiatry service time for non-ALC patients (Victoria hospital, 2014-2016, n=2586)

Figure 2.12 shows that roughly 30% of patients only need ≤2 days at the ward, however the rest of the service distribution is very drawn out, and a sizable number (3.6%) stay at Inpatient Psychiatry for more than 60 days. Some of those long stays can be attributed to ALC patients, which shows in the service time measures when looking at ALC and non-ALC patients separately:

- **All patients** – service time mean: 17.3 days, 90th percentile: 42.7 days
- **ALC patients** – service time mean: 97.2 days, 90th percentile: 205.2 days
- **Non-ALC patients** – service time mean: 16.0 days, 90th percentile: 41.0 days

A box plot comparing ALC and non-ALC patient IP MH length of stay times (from moment of registration to discharge) is included in Appendix C – Box plot Inpatient Psychiatry length of stays.

Concurrent number of admitted patients

The number of concurrent admitted patients to Inpatient Psychiatry shows the utilization of the beds. The number of admitted patients includes those who have been admitted but are waiting in the ED for a bed to become available.

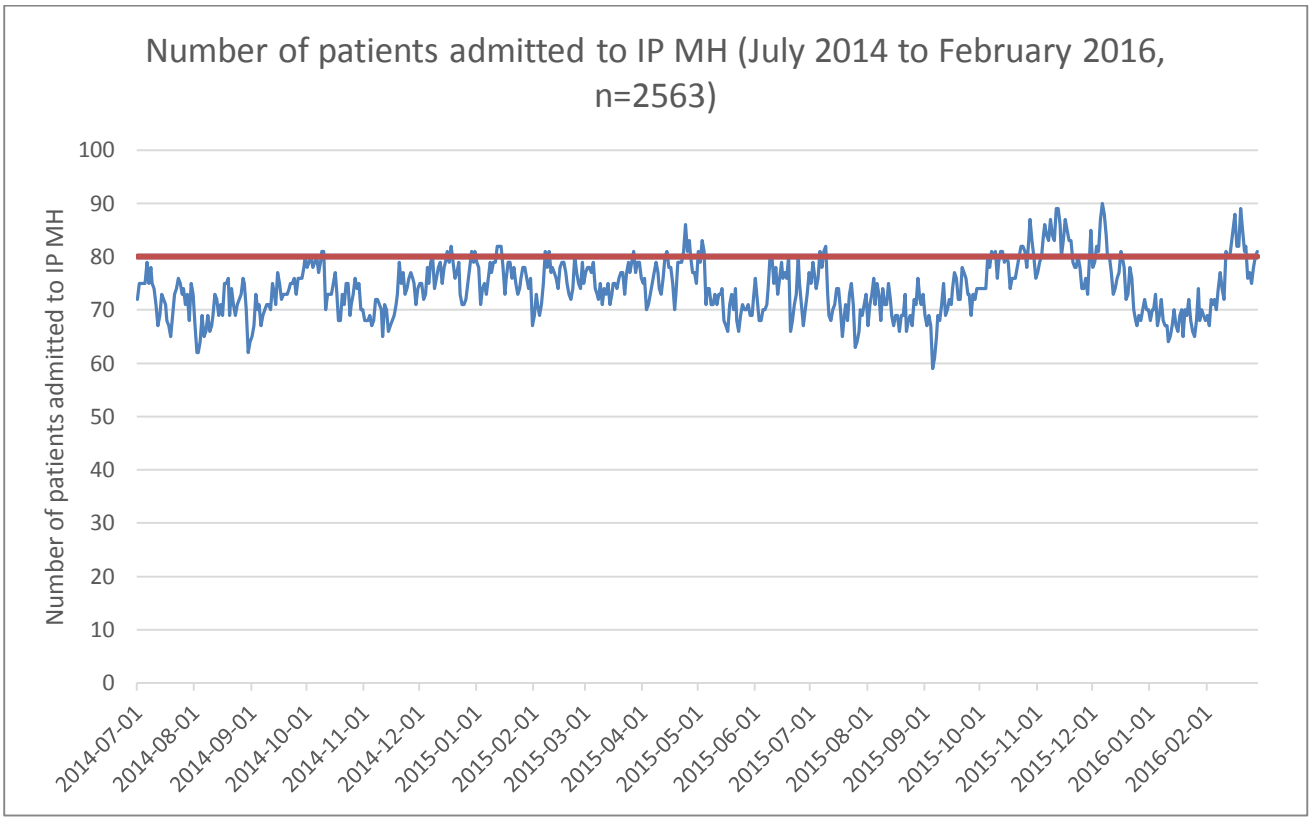

Figure 2.13 – Concurrent number of admitted patients to IP MH (Victoria hospital 2014-2016, n=2563)

Figure 2.13 shows Inpatient Psychiatry constantly operating near or sometimes even over capacity. The average number of admitted patients over this period is 74, giving an average bed utilization of 92.7%.

Alternative Level of Care (ALC) percentage

As the measure 'Service time' above highlighted, the time ALC patients spend at Inpatient Psychiatry is quite extreme, cases of more than a year at the ward have occurred. The capacity that this group uses is of interest.

Out of 2916 mental health patients over the period 2014 – 2016, 47 patients (1.6%) were designated as ALC. However, those ALC patients accounted for 10.1% of the bed days.

ALC summary	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Grand total
ALC days	129	209	194	139	199	314	257	229	218	300	356	348	2892
ALC patients	5	8	8	6	8	11	12	9	9	13	13	16	36

Table 2.1 – ALC summary for Inpatient Psychiatry (Victoria hospital, April 2015 – March 2016)

Table 2.1 shows one year of ALC data, the number of ALC patients per month and the total number of ALC days. ALC patients take up anywhere from 5.4% (129 / 30*80) in to 15.9% (356 / 28*80) of bed days. It is difficult to say if an upward trend exists, more years of data would be needed to assess that.

Patients designated as ALC have significantly higher length of stay compared to non-ALC patients, and take up a significant amount of bed capacity during a year. Beds occupied by ALC patients cannot be used to provide care to new mental health patients arriving, and they contribute to the bed shortage, as well as driving up waiting time for patients upstream (e.g. in the Emergency department).

2.3.4 CONCLUSIONS FROM THE DATA ANALYSIS

At the 'beginning' of the Emergency department there seems to be no difference in waiting compared to other patient types. The Psychiatry consult takes longer compared to arrive compared to the average, but in the grand scheme of things the biggest waiting time for a mental health is definitely the 'Time to bed', which takes on average 1.5 days for a patient to actually move to Inpatient Psychiatry, which leads to an average of 6 admitted patients waiting for an IP bed while in the ED.

At Inpatient Psychiatry, there seems to be a split between patients that can be discharged within 2 days, and those that take longer. The service time distribution is quite flat, meaning variation in the service times of patients is quite high. Bed utilization of Inpatient Psychiatry is approximately 93%, which is high. ALC patients use a substantial amount of capacity that could otherwise be used to provide care to more patients, and the bed usage likely increases the waiting time for an inpatient bed.

	Mean	90th percentile
ED length of stay (all patients)	6h 35m	
ED length of stay (only MH patient)	20h 11m	
ED initial wait (all patients)	1h 51m	
Time to consult (any consult service)	2h 13m	4h 21m
Time to CEPS consult	3h 49m	8h 20m
Time to bed	1.51 days	3.51 days
Number of patients waiting for IP MH bed	6.17	
Percentage of days >8 patients waiting for a bed	19.9%	
Number of MH patients in the ED	8.16	
Percentage of days >8 MH patients in the ED	42.8%	
IP MH service time (all patients)	17.3 days	42.7 days
IP MH service time (ALC patients)	97.2 days	205.2 days
IP MH service time (non-ALC patients)	16.0 days	41.0 days
Number of patients admitted to IP MH	74	
IP MH bed utilization	92.7%	
Percentage of ALC bed days	10.1%	

Table 2.2 – Summary of data analysis on data Victoria hospital 2014-2016

2.4 PROBLEM CLUSTER ANALYSIS

The problem cluster (see Figure 2.14) shows problems related to high waiting times for mental health patients at Victoria and their relationship. We use the problem cluster to give a clear overview of the situation, and it is useful in determining the root problems that should be dealt with.

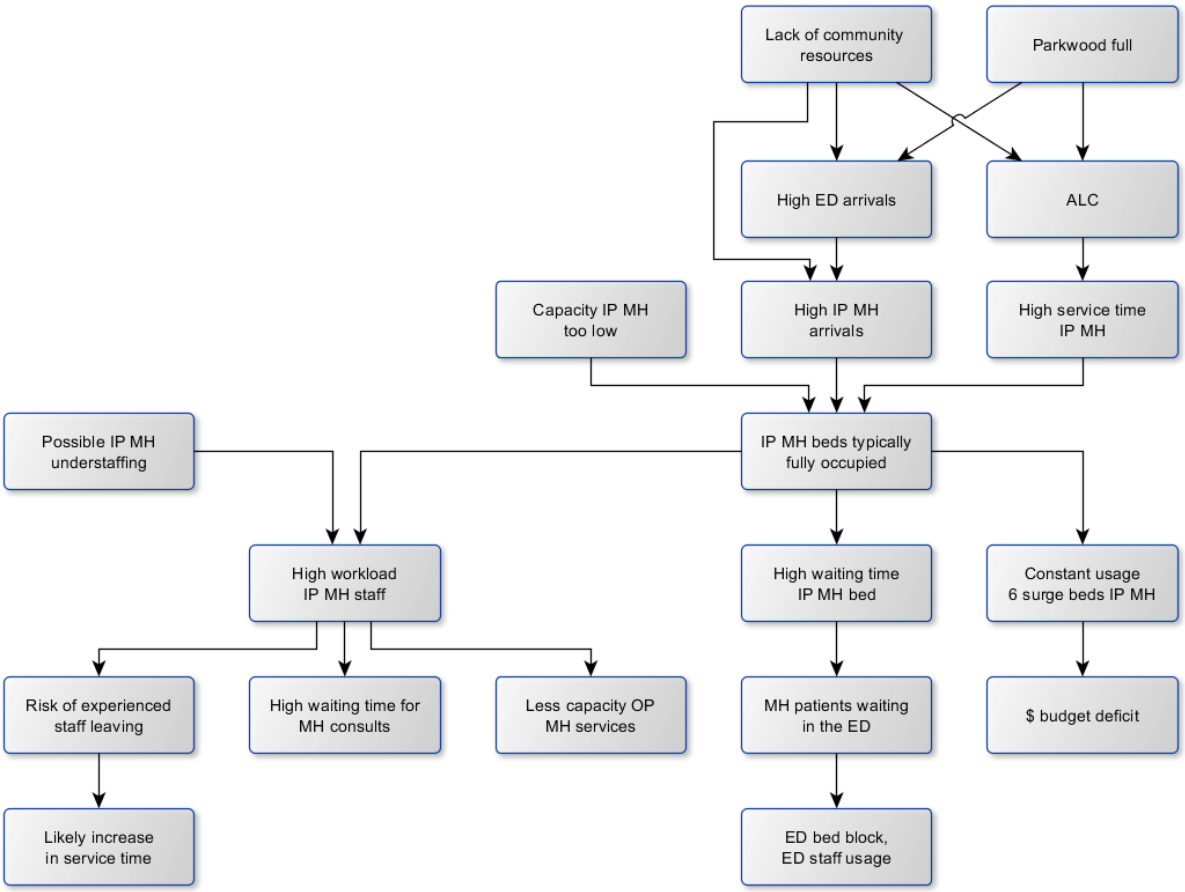

Figure 2.14 - Problem Cluster
IP MH: Inpatient mental health department (used interchangeably with Inpatient Psychiatry)

Lack of community resources – Some patients that could be served with community resources (e.g. visiting psychiatrist outside of the hospital) for various reasons still go the ED, leading to ***high ED arrivals***. The lack of community resources is also a problem at the other end of the chain, where patients have received the care needed by the hospital, but cannot be discharged from the hospital because a lack of nursing home spots for example, leading to more ***ALC***.

Parkwood full – The Parkwood hospital is supposed to take on the mental health patients that need long term care. However, because it is full, patients that should arrive to Parkwood go to Victoria instead (***high ED arrivals***). In addition: mental health patients that are supposed to get transferred from Victoria to Parkwood have to stay at Victoria (***ALC***), resulting in higher bed use.

High IP MH arrivals – The ***high ED arrivals*** and a ***lack of community resources*** to divert some of those patients to, results in a higher number of IP MH arrivals than would otherwise be the case, which is one of the factors for ***IP MH beds typically being fully occupied***.

High service time IP MH – Mainly because of ***ALC***, the service time for IP MH is higher than it should be, and is also an important factor for ***IP MH beds typically being fully occupied***.

Capacity IP MH too low – A third (possible) factor for ***IP MH beds typically being fully occupied*** is that the amount of beds (capacity) is simply inadequate.

IP MH beds typically being fully occupied – At the core of the problem cluster, high bed occupancy leads to ***High waiting time for IP MH bed***, which in turn leads to ***MH patients waiting in the ED***, and ***ED bed block, ED staff usage***. It also increases the workload for IP MH staff.

High workload for IP MH staff – The almost constant full IP MH bed occupancy, in combination with (possible) understaffing leads to a ***high workload for IP MH staff***. This in turn leads to psychiatrist having ***less time available to see mental health outpatients***, ***high waiting time for MH consults*** when ordered by other departments, and also increases the ***risk of experienced staff leaving the hospital***, leading (presumably) to ***higher service times*** (since experienced psychiatrists can serve patients quicker).

Constant use of 6 surge beds – The IP MH department has 6 unfunded surge beds, originally meant to deal with sudden temporary increases in patient arrivals. Currently these 6 beds are constantly in use, leading to a ***budget deficit***.

2.5 CONCLUSIONS

Based on the waiting time measures from Section 2.3 we conclude that mental health patients at Victoria indeed experience long waiting times. The 'initial wait' is the same as other patients, but the average waiting time for a Psychiatry consult to arrive is 3 hours and 49 minutes (1 hour and 36 longer than the average of all consult wait times). The most significant waiting time however is the time between decision to admit to Inpatient Psychiatry and when the patient can enter the ward: the average time to bed is 1.51 days, the 90th percentile is 3.51 days.

The problem cluster in Section 2.4 shows what problems contribute to this, and how they relate to each other. The important problems regarding adult mental health patients' waiting time all form around the problem in the center of the problem cluster: *IP MH beds being typically fully occupied*. This seems to be the main cause of long wait times the patients experience, as well as the high number of ED beds used by mental health patients waiting for an Inpatient Psychiatry bed.

Three problems contribute to the high bed occupancy: more patient arrivals (because of lack resources outside the hospital), long length of stay (of which ALC patients play a big role) and possibly an insufficient number of inpatient beds.

Narrow scope to Inpatient Psychiatry

Because the waiting time for Inpatient Psychiatry is significantly higher than the waiting time adult mental health patients experience due to Emergency department operations, we narrow the scope to Inpatient Psychiatry. In order to decrease the waiting time for adult mental health patients at Victoria, the rest of the report focuses on finding interventions that increase the bed availability of Inpatient Psychiatry.

3 THEORETICAL FRAMEWORK

To effectively analyze the situation at Victoria hospital, a literature search is performed in order to incorporate as much current relevant knowledge on modeling and analysis of wait times in hospitals, and find articles related to the analysis of the impact of ALC patients on waiting times in hospitals. We apply the relevant knowledge in the analyses in later chapters.

Section 3.1 discusses the literature search strategy we use to find relevant articles. Section 3.2 discusses the methods used in the literature to model and analyze waiting times in hospitals. Section 3.3 discusses the impact of ALC patients on the hospital, as well as the underlying problems. Section 3.4 concludes with the implications of the found literature for this research.

3.1 LITERATURE SEARCH STRATEGY

We use Google Scholar as the search engine since it covers most scholarly documents, Khabsa & Giles (2014) estimate roughly 90%. For each search term the first 30 articles are examined based on abstract and content, and useful articles are selected. After each search the search term is modified based on (irrelevant) results from the previous search term. Then as a second step a forward search is performed on the relevant articles found to include related and possibly newer knowledge. The search terms used and number of relevant articles found per search term are shown in Appendix E.

3.2 METHODS FOR ANALYSIS OF WAIT TIMES IN HOSPITALS

Law (Law, 2015) describes the ways one can study a system in Figure 3.1.

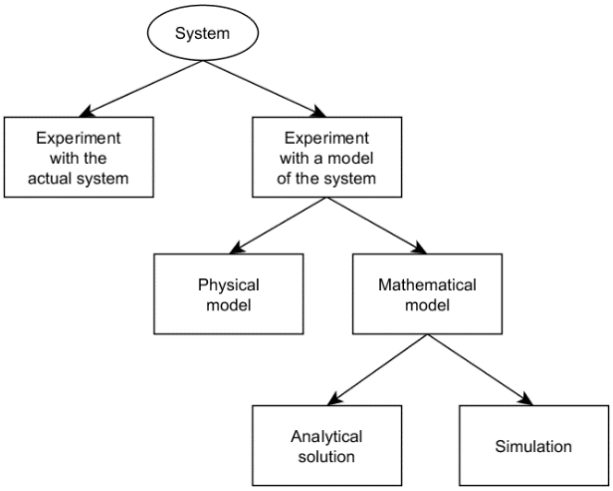

Figure 3.1 – Ways to study a system (Law, 2015)

Experimenting with the actual system is often infeasible and/or too expensive (e.g. adding / removing beds). For this reason, it is usually necessary to build a model of the system and experiment with that. A *mathematical model* represents a system in logical and quantitative relationships that can be changed to see how the system would react (if the model is accurate). If a mathematical model is simple enough, it may be possible to get an exact, *analytical solution*. However, many systems are highly complex, precluding an exact analytical solution to be found, in which case computer simulation can be used to numerically assess performance.

Since in this case experimenting with the actual system is not possible, the question on what the most suitable method to model the Inpatient Psychiatry department is remains.

Many studies in the literature have modeled a (part of) a hospital in order to study how the system performs when for example beds are added, or staff-scheduling is changed. Table 3.1 gives an overview of the methods used in analyses of wait times in hospitals.

Author	Title	Year	Simulation	Analytical	Comments
Gul & Guneri	A computer simulation model to reduce patient length of stay and to improve resource utilization rate in an emergency department service system	2012	X		Uses simulation model to reduce patient length of stay through minor changes in shift hours and number of resources.
Kembe, Onah, & Iorkegh	A study of waiting and service costs of a multi-server queuing model in a specialist hospital	2012		X	Uses an M/M/s queueing model, balances service costs and waiting costs
Wang, Li, & Howard	A system model of work flow in the patient room of hospital emergency department	2013		X	Models network of services, assumes M/M/s/∞ characteristics
Dai & Shi	A Two-Time-Scale Approach to Time-Varying Queues in Hospital Inpatient Flow Management	2015		X	Uses an '$M_{peri}/Geo_{2timeScale}/N$' queuing model that handles time dependent behavior
Bagust, Place, & Posnett	Dynamics of bed use in accommodating emergency admissions: stochastic simulation model	1999	X		Models the relation between variable demand and bed capacity, the risk of having no bed available
Eskandari, Riyahifard, Khosravi, & Geiger	Improving the emergency department performance using simulation and MCDM methods	2011	X		Uses simulation to estimate reduced waiting time in different scenarios, scores scenarios using AHP.
Wang, Quan, Li, & Hollis	Modeling and analysis of work flow and staffing level in a computed tomography division of University of Wisconsin Medical Foundation	2012		X	Uses a Markov chain model assuming M/M/s, to evaluate different staffing and capacity (CT equipment) configurations
Duguay & Chetouane	Modeling and Improving Emergency Department Systems using Discrete Event Simulation	2007	X		Simulated an ED in Canada to reduce waiting times and improve overall service delivery.
de Bruin, van Rossum, Visser, & Koole	Modeling the emergency cardiac in-patient flow: an application of queuing theory	2007		X	Uses M/M/c/c 2 dimensional Markov process with blocking to give the patient refusal % for different number of beds

Harper & Shahani	Modelling for the planning and management of bed capacities in hospitals	2002	X		Models a hospital with different departments, and takes many factors into account. Balances number of patient refusals with the number of beds.
Shi, Chou, Dai, Ding, & Sim	Models and Insights for Hospital Inpatient Operations: Time-Dependent ED Boarding Time	2015	X		Uses a stochastic network model to estimate the impact of inpatient flow on patients waiting in the ED for inpatient beds and identify bottlenecks.
Wang, Li, Tussey, & Ross	Reducing Length of Stay in Emergency Department: A Simulation Study at a Community Hospital	2012	X		Uses a simulation model to estimate the improvement different scenarios could attain.
Abo-Hamad & Arisha	Simulation-based framework to improve patient experience in an emergency department	2013	X		Uses simulation model of the ED and multi-criteria decision analysis to identify the intervention that improves the overall situation the most.
Wong, Wu, Caesar, Abrams, & Morra	Smoothing inpatient discharges decreases emergency department congestion: a system dynamics simulation model	2010	X		Uses simulation of an inpatient ward and ED to assess impact of smoothing inpatient discharges on ED congestion.
Cochran & Bharti	Stochastic bed balancing of an obstetrics hospital	2006	X	X	Implements both a queueing network and simulation model. Queueing network for a rough impression of the system and initial bed balancing. Simulation is used to more accurately estimate waiting, sojourn times, and blocking behavior.
Gorunescu, McClean, & Millard	Using a queueing model to help plan bed allocation in a department of geriatric medicine	2002		X	Uses a M/PH/c/N queueing model to estimate the impact of changes in arrival rate, length of stay, and capacity.

Table 3.1 – Methods used in health care modeling studies

In addition to these papers, the literature overview paper by Hulshof, Kortbeek, Boucherie, Hans, & Bakker (2012) also paints a similar picture. In cited papers discussing the bed capacity dimensioning for inpatient care services, roughly half of the papers use computer simulation, the other half use queueing theory or Markov processes (a few papers use mathematical programming).

3.2.1 APPROPRIATE MODELING METHOD

Saghafian, Austin, & Traub (2015) discuss when certain modeling methods are appropriate. On queuing theory: "Although analytical methods contain less details than simulation, and are based on simplified models, it could provide quick results and an opportunity to investigate system properties more efficiently under appropriate assumptions". Most papers that use queueing theory assume patient arrivals and service times to be exponentially distributed (noted by 'M/M/' in Kendall notation), do not account for blocking (when all beds are full), and assume arrival and service rates to be stationary in time. The time dependent $M_t/M_t/\infty$ model is only accurate if the department is occupied with less than 15 patients.

On computer simulation Saghafian et al. (2015) state "Process model simulation approach seems to be much more flexible and versatile. It is free from assumptions of the particular type of the arrival process (Poisson or not), as well as the service time (exponential or not)". (de Bruin et al., 2007) also note simulation can be useful when time-varying arrival rates need to be accounted for, and when length of stay data cannot be fit by any distribution.

3.3 IMPACT OF BED BLOCKING (ALTERNATIVE LEVEL OF CARE)

The impact of ALC patients on the available capacity (and thus on the waiting time) is indicated in Section 2.3.3, roughly 10% of all bed days over April 2015 – March 2016 were by ALC patients.

Costa, Poss, Peirce, & Hirdes (2012) with their analysis of multiple Canadian hospitals find that 41.5% of ALC patients were waiting for nursing home admission. Staff interviewed at Victoria hospital also indicated lack of access to nursing homes as one of the lead causes of bed blocking or ALC days. Other important indicators were morbid obesity, psychiatric diagnosis, abusive behaviors and stroke. A large reduction of ALC days can likely be achieved by improving nursing home admissions.

Patrick (2011) also named the lack of access to long-term care as a reason for congested inpatient wards, leading to congestion at the Emergency department. He presents a Markov decision process model that determines the required access to long-term care in order for the census of patients waiting for LTC in the hospitals to remain below a given threshold.

Esensoy & Carter (2015) have created a quantitative model to look at patient flow at the LHIN level, including acute hospital care, home and community care, rehabilitation and complex community care, long-term care homes and informal care. Performing a study like this might be useful to help push for more capacity at facilities outside the hospital (e.g. in nursing homes), reducing the number of ALC patients.

3.4 IMPLICATIONS FOR THIS RESEARCH

Roughly half of various case studies listed in Section 3.2 use computer simulation, the others use queueing theory or Markov processes. Saghafian et al. (2015) discuss which method is appropriate under what circumstances. If the mathematical model is simple, queueing theory can be used to get an analytical solution. If the mathematical model is too complex (e.g. if the service time distribution cannot be fit to a theoretical distribution) simulation is more appropriate to analyze the Inpatient Psychiatry department.

The lack of access to long-term care outside the hospital and subsequent congestion at inpatient wards and emergency departments is described in the literature. The articles described in Section

3.3 recognize that a broader scope is needed, taking capacity outside the hospital into account. Additionally, beds outside the hospital might be cheaper, so increasing the capacity at facilities outside the hospital could be a cheaper way overall to reduce waiting times for mental health patients. Quantifying the impact ALC patients have on the waiting time at Victoria is of interest.

4 INTERVENTIONS OF INTEREST

We conclude in Chapter 2 that adult mental health patients at Victoria experience long waiting times, mostly due to the Inpatient Psychiatry beds that are almost always full, which is in turn caused by other problems as shown in the problem cluster (Section 2.4). The factors that influence waiting time for the patients are listed in Section 4.1. Based on these factors four interventions are likely to decrease the waiting time are proposed in Section 4.2.

4.1 FACTORS THAT INFLUENCE WAITING TIME

This chapter presents some possible interventions that are different from the current situation, namely in one of the three important factors for waiting time:

- Arrival rate – the number of patients admitted to Inpatient Psychiatry (Section 4.2.1)
- Service time – the time patients spend at Inpatient Psychiatry (Section 4.2.2 & 4.2.3)
- Capacity – the number of beds at Inpatient Psychiatry (Section 4.2.4)

Changes in these factors will have impact on the waiting time of adult mental health patients, so the proposed interventions should change one of the three factors in order to decrease waiting time.

4.2 INTERVENTIONS

In order to decrease the waiting time for mental health patients at Victoria, a few interventions are proposed. The interventions described in the following sections give an idea of how the change in one of the three factors *could* be achieved, but any changes in the hospital that impact the arrival rate, service time, or capacity at Inpatient Psychiatry will achieve similar reduction of waiting time.

4.2.1 INTERVENTION 1: PATIENT REALLOCATION TO OTHER HOSPITALS

The number of patient that get admitted to Inpatient Psychiatry is an important factor for how busy the department is, and is linked with the high waiting time for mental health patients. In interviews with hospital staff the lack of resources outside the hospital such as community support or outpatient capacity at Parkwood were mentioned as reasons for higher number of arrivals to Victoria. A possible intervention is to reallocate more patients to less busy hospitals in the area, decreasing the number of arrivals to Inpatient Psychiatry and thus reducing waiting time. Since the hospitals in the area are part of a Local Health Integration Network (LHIN) some collaboration might be possible.

Some physicians have noted that not all patients are willing to go to other hospitals, and at the end of the hospital stay additional work might be needed to setup the follow-up plan in the original area. These possible drawbacks are important to keep in mind, however the aim of this analysis is only to give an indication of what the impact could be on the high waiting time at Victoria, not to present a full-fledged plan ready for execution.

4.2.2 INTERVENTION 2: REDUCING INPATIENT PSYCHIATRY SERVICE TIME

As Section 2.3.3 shows, the service time (the time patients spend in a Inpatient Psychiatry bed) has quite a long 'tail', meaning there are patients that stay for longer than 60 or 80 days, in a few cases even as long as a year. Roughly 10% of bed-capacity is used by ALC patients, who cannot be discharged for various reasons.

What if all service times were reduced by a certain percentage? What would be the impact of reducing the service time at Inpatient Psychiatry by 1%, 2%, 5% or even 10%? Not all are realistic to achieve, and quality of care must not be forgotten, but an indication of what impact these scenarios have on the waiting time of mental health patients can be insightful.

4.2.3 Intervention 3: No patients stay for longer than certain number of days

Reducing the service time of someone who stays for 100 days might be easier than for a patient who only stays for 1 day. So instead of reducing *all* service times with a certain percentage, what would be the expected impact on waiting time if no patients would ever stay longer than 300, 200, 100, 80 or 60 days? What would the impact be on bed availability and on the waiting time for mental health patients? Evaluating these scenarios will more clearly quantify the effect ALC patients have on the waiting time.

4.2.4 Intervention 4: Increasing the Inpatient Psychiatry capacity

And the third important factor is the number of patients that can be helped simultaneously at Inpatient Psychiatry. If a thousand patients could be treated at the same time it is unlikely a lack of capacity exists and waiting time is also unlikely. Section 2.3.3 shows Inpatient Psychiatry has a utilization of 93% (July 2014 – February 2016), which is high for a system with variable arrivals and service times.

If no changes can be made to the number of patient arrivals or their service times, the capacity can be increased to reduce waiting times. What would the impact of adding additional Inpatient Psychiatry beds be on the waiting time for mental health patients?

4.3 Conclusion: interventions of interest

The estimated effect of these four interventions will give an indication on what is needed to achieve certain reductions of waiting time for adult mental health patients at Victoria. The four proposed interventions are:

- Intervention 1: Patient reallocation to other hospitals
- Intervention 2: Reducing Inpatient Psychiatry service time
- Intervention 3: No patients stay for longer than certain number of days
- Intervention 4: Increasing the Inpatient Psychiatry capacity

Chapter 5 establishes a model of Inpatient Psychiatry that is used to estimate the impact of these interventions on the waiting time. The estimated impact of these interventions is discussed in Chapter 6.

5 MODEL

5.1 APPROACH

In this chapter we construct a mathematical model that can be experimented with to evaluate the expected effect of scenarios and interventions determined in Chapter 0.

The first step is to perform a problem analysis, see Section 5.2. Based on the problem definition a conceptual model is constructed in Section 5.3. Section 5.4 discusses the data needed for the model and specifies the model parameters and input distributions. Based on the available data and the model complexity a choice is made for the analysis method (e.g. simulation or queueing theory) in Section 5.5. The conceptual model is implemented to the analysis method of choice in Section 5.6, and verification and validation are performed. Section 5.7 discusses the experimental design. Section 5.8 will list the conclusions of this chapter.

5.2 PROBLEM DEFINITION

In Section 2.5 we conclude the core problem is Inpatient Psychiatry beds typically are fully occupied. The three important factors that are linked to this are: patient arrival rate, the service time and the capacity at Inpatient Psychiatry. Since the time to bed is by far the biggest contributor to waiting times for mental health patients at Victoria, we focus our model only on the Inpatient Psychiatry department.

The experimental factors that the model needs to handle – in order to evaluate the scenarios and interventions discussed in Chapter 0 – are changes to the arrival rate, the service time and the capacity at Inpatient Psychiatry.

5.3 CONCEPTUAL MODEL

The conceptual model is shown in Figure 5.1, listing the process steps of the model. The bottom labels show the data requirements for certain parts of the model. As discussed in the previous

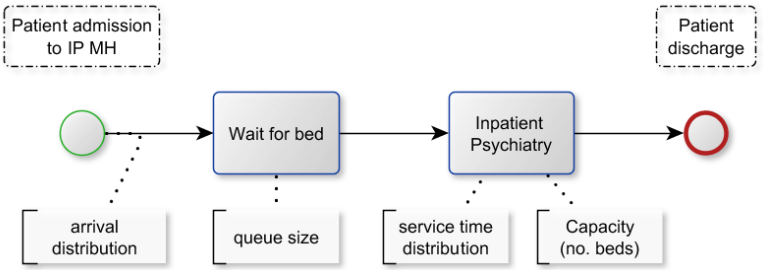

Figure 5.1 - Conceptual model with processes and data requirements

section, only the Inpatient Psychiatry department will be modeled. The Inpatient Psychiatry department will be modeled as a 'black box': patients are admitted, if necessary wait for a bed, then enter the ward. Patients stay for the time dictated by the service time distribution, the capacity (number of beds) determines how many patients can be served simultaneously. Inpatient Psychiatry is modeled as a black box in order to keep the model relatively simple, which is in accordance with the scope of the problem and proposed interventions and scenarios.

5.4 DATA GATHERING AND MATHEMATICAL MODEL

In order to translate the conceptual model into a mathematical model, data needs to be gathered and analyzed on these four characteristics:

1. Inter-arrival time distribution: how often do patients arrive and in what pattern?
2. Service time distribution: how long do patients stay at the ward and in what distribution?
3. Number of servers: how many patients can be helped at once?
4. Queue size: maximum number of patients that can wait simultaneously?

The following sections discuss the data analysis for each of these characteristics.

5.4.1 INTER-ARRIVAL TIME DISTRIBUTION

The inter-arrival time distribution describes how much time is between patient arrivals. An 'arrival' in this project equals an admission to Inpatient Psychiatry. In general, non-elective patient arrivals can often be described with an exponential distribution (see case studies in Section 3.2).

Distribution fitting

No distribution fits to the inter-arrival times when all arrivals are grouped together (see Appendix F.1). Similarly, no distribution fits on inter-arrival times split per day of the week (see Appendix F.2 – Arrival distribution per day of the week).

However, when inter-arrival times are grouped based on hour of the day (i.e. arrivals from 00:00 to 01:00 grouped, and 01:00 to 02:00, etc.) for some groups the exponential distribution is a good fit. The arrivals between 00:00 and 09:00 fit to the exponential distribution and pass the goodness-of-fit tests. Arrivals later than 09:00 do not fit however. This is likely because arrival patterns of different days are very similar between 00:00 and 09:00, but differ quite significantly after 09:00. See Appendix F.3 for details on the hour of day distribution fitting.

Conclusion

Since the exponential distribution fits well to the arrivals when the daily patterns are the same, we choose an exponential distribution with changing arrival rate per day and per hour. The exponential distribution is also fitted per hour of the day, with all days grouped together. During the night, where the pattern of arrivals is quite similar this provides a good fit, however during the day the differences between days become too large, and a single per hour distribution does not provide a good fit. This suggests arrivals are likely exponentially distributed, however the differences between days might be too large for a single distribution fit where days are grouped together. See Appendix F.4 – Arrival distribution per day and per hour for the resulting parameters.

5.4.2 *Service time distribution*

The service time distribution describes how long a patient stays at Inpatient Psychiatry, and the chance of a certain service time occurring (e.g. a service time of 100 days is less likely than a service time of 15 days).

Distribution fitting

No distribution fits to the IP MH service times (see Appendix G – Service time theoretical distribution fitting). As Figure 5.2 shows, the service time histogram is not smooth, service times of [0,2] days occur often, as well as relatively many service times of >60 days. Appendix G – Service time theoretical distribution fitting shows a large spike of IP MH service times between 0 and 0.01 day (14.4 minutes). It is likely the patients that were waiting for an IP MH bed in the ED did not need admission anymore by the time a bed became available.

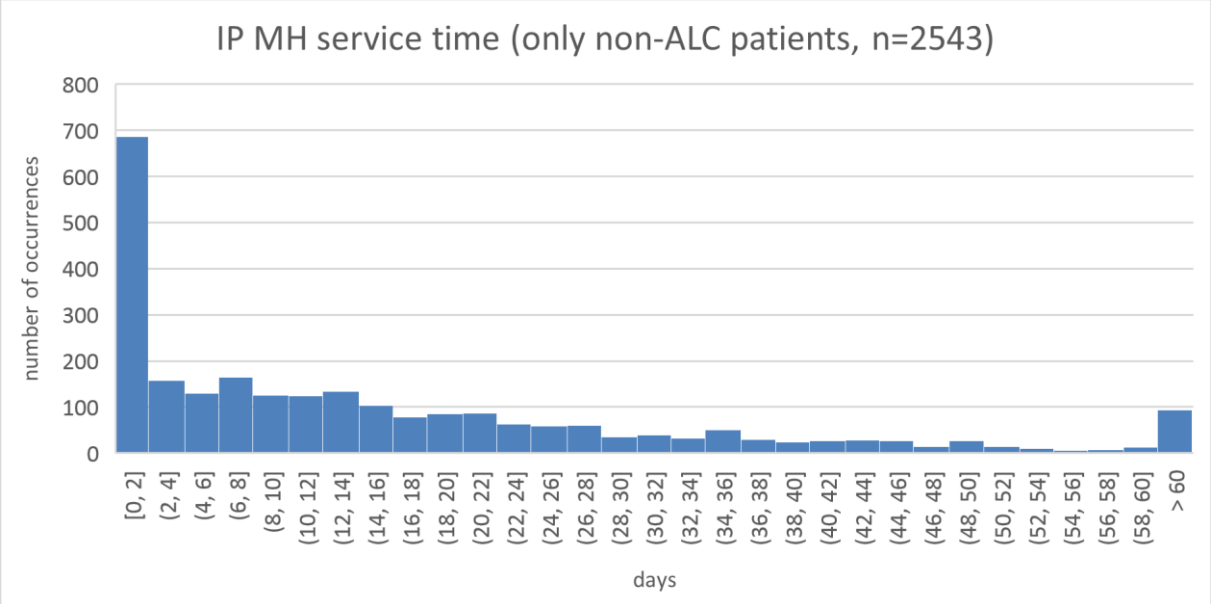

Figure 5.2 – IP MH service time histogram (Victoria hospital 2014 – 2016, n=2543)

The spike of IP MH service times between 0 and 0.01 day and >60 days might distort the picture, so another attempt to fit a distribution is made where values below 0.25 days and above 60 days are filtered out. Again, no suitable distribution is found (Appendix G – Service time theoretical distribution fitting). Law (2015) recommends using an empirical distribution when no theoretical distribution is appropriate, which might occur if data are a mixture of two or more heterogeneous populations. In this case those groups could be: patients that are admitted to Inpatient Psychiatry but never occupy a bed there, 'normal' IP MH patients and ALC patients.

Conclusion

Because no theoretical distribution provides a good fit to the data (possibly because of multiple heterogeneous populations in the data), even when suspected outliers are filtered out, an empirical distribution is likely the best approach to model the service times.

5.4.3 *Number of servers*

The number of servers represents how many patients can be helped at once, in the case of Inpatient Psychiatry this is the same as the number of beds: 80.

Since no data is available on switches between regular beds and PICU beds, or even a difference in waiting times and service times of PICU patients and regular patients, no distinction between those beds is made in this model.

5.4.4 *Queue capacity*

Since patients are almost never turned away, but usually wait or in some cases get transferred to other hospitals, we do not consider there to be a limit to the number of patients in queue, but rather assume an infinite queue length. Preferably the queue length should not exceed 8, but it is possible in the model to allow for fair comparison between different scenarios.

5.4.5 *Overview of the model*

The resulting mathematical model has time-dependent, exponentially distributed arrivals, an empirical service time distribution, 80 beds of capacity, and an infinite queue length.

5.5 Choice of analysis method

The combination of time-varying arrival rates and the empirical service time distribution make the model complex. Analyzing the behavior of this model using Queueing Theory (or Markov processes) would be very complicated if not impossible, so we choose Computer Simulation as the method of analysis.

5.6 Simulation model

The mathematical model is built into a simulation model, see Figure 5.3 for an impression.

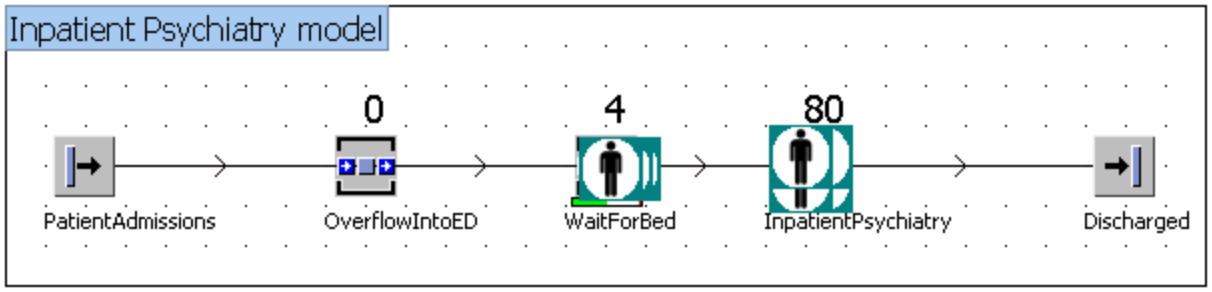

Figure 5.3 – Screenshot of the Inpatient Psychiatry simulation model

The simulation model if different on one entity from the conceptual model, an additional queue is added to the model, but only for easier measurement on how often more than 8 patients are waiting for a bed, functionally they are the same.

The simulation model changes the arrival rate of patients per day and per hour, and it uses the empirical service time distribution to determine how long a patient stays at Inpatient Psychiatry. The number of beds is set to 80. In the simulation model a patient arrives, if necessary waits for a bed to become available, moves into a bed, stays there for the service time duration and is then

discharged. In order to increase accuracy of the model, the discharge rates per day and per hour are also taken into account. See Appendix H.1 – Simulation model details for a detailed overview of the simulation model.

Verification and validation

There are two important steps in using a simulation model. The first check is *verification*: does the simulation model match with the conceptual model? The second check is *validation*: does the model represent reality well enough?

The model corresponds with the conceptual model, and runs without errors, so verification is taken care of. After the first simulation runs the waiting times and number of patients were lower than in the historical data. To correct for this the model has been adjusted: the patient service time is adjusted upon entry into Inpatient Psychiatry in order to make discharges during the day more likely, and discharges during the night less likely. See Appendix H.1 – Simulation model details for a more detailed explanation. For validation, some performance measures match up almost exactly, the percentage of time more than 8 patients are waiting for a bed matches up perfectly, and the service time and utilization rate too. The waiting time and number of patients in the queue is optimistic in the model, and the sojourn time is somewhat pessimistic. For the purpose of this evaluation the accuracy is sufficient. See Appendix H.2 – Simulation model validation for details on the validation.

5.7 EXPERIMENT DESIGN

Various approaches can be taken with the experiments. The simulation model has 6 settings that can be adjusted per experiment: number of IP beds, service time distribution with/without ALC patients, arrival rate percentage adjustment, service time percentage adjustment, minimal and maximum service times. For this project we are interested in the effect each individual factor has on the performance of Inpatient Psychiatry, less in the combined effect of the variables. So we choose the one-factor-at-a-time (OFAT) method of experimental design.

Table 5.1 shows the input settings of the simulation model we choose for each intervention. For every intervention small differences are evaluated, for example a 1% or 2% decrease in arrival rate for intervention 1. To show the sensitivity of the waiting time in each scenario some larger changes are also shown, like a 10% decrease in service time. The service time cut-off points for intervention 3 are based around the highest service times found in historical data (345 days), so the highest maximum service time is 300. The number of beds increases in small steps of 2 beds since adding beds is very expensive, so evaluating the performance of 10 or 20 more beds is not needed, since it is unlikely that many beds are added.

Baseline (current situation)				
Beds	Arrival rate modifier	Service time modifier	Minimum service time	Maximum service time
80	1.00	1.00	0 days	1000 days
Intervention 1: Patient reallocation to other hospitals				
Beds	**Arrival rate modifier**	Service time modifier	Minimum service time	Maximum service time
80	**0.99**	1.00	0 days	1000 days
80	**0.98**	1.00	0 days	1000 days
80	**0.95**	1.00	0 days	1000 days
80	**0.90**	1.00	0 days	1000 days

Intervention 2: Reducing Inpatient Psychiatry service time				
Beds	Arrival rate modifier	**Service time modifier**	Minimum service time	Maximum service time
80	1.00	**0.99**	0 days	1000 days
80	1.00	**0.98**	0 days	1000 days
80	1.00	**0.95**	0 days	1000 days
80	1.00	**0.90**	0 days	1000 days
Intervention 3: No patients stay for longer than certain number of days				
Beds	Arrival rate modifier	Service time modifier	Minimum service time	**Maximum service time**
80	1.00	1.00	0 days	**300 days**
80	1.00	1.00	0 days	**200 days**
80	1.00	1.00	0 days	**100 days**
80	1.00	1.00	0 days	**80 days**
80	1.00	1.00	0 days	**60 days**
Intervention 4: Increasing the Inpatient Psychiatry capacity				
Beds	Arrival rate modifier	Service time modifier	Minimum service time	Maximum service time
82	1.00	1.00	0 days	1000 days
84	1.00	1.00	0 days	1000 days
86	1.00	1.00	0 days	1000 days
88	1.00	1.00	0 days	1000 days

Table 5.1 – Simulation settings for each intervention

5.8 CONCLUSIONS

As a conceptual model we choose a multi-server queue with a time-dependent arrival rate, which is exponentially distributed and an empirical service time distribution, with 80 beds of capacity and an infinite queue length. This conceptual model is implemented in a computer simulation model, because the arrival and service time distributions make the model too complex for Queueing Theory. The simulation model is verified and validated. For the experimental design we choose the one-factor-at-a-time method. In the next chapter the scenarios and interventions defined in Chapter 0 are evaluated.

6 SIMULATION RESULTS

Now that the current waiting time and other performance measures are known (see Section 2.3) the important question is: what can be done about it? This chapter does not focus on any medical or clinical changes. It only assesses what e.g. the waiting time or bed utilization would be if the number of patient admissions decreases by 2%, or if the number of ALC patients decreases by 2 for example. We evaluate the scenarios and interventions of interest from Chapter 0 using the simulation model constructed in Chapter 5.

Sections 6.1**Error! Reference source not found.** through Section 6.4 **Error! Reference source not found.**discuss the expected impact of a scenario or intervention, Section 6.5 discusses the limitations of this analysis, and Section 6.6 discusses the conclusions.

6.1 INTERVENTION 1: PATIENT REALLOCATION TO OTHER HOSPITALS

This scenario explores the impact of reallocating a certain percentage of current admissions to other hospitals. This basically reduces the number of patients that enter Inpatient Psychiatry.

Arrival rate reduction	Time to bed (hrs)	Queue length	Service time (days)	LOS (days)	>8 in queue	Bed utilization
-	28.7	5.0	17.6	18.8	20.2%	91.8%
1%	22.3	3.9	17.6	18.5	16.4%	90.9%
2%	17.5	3.0	17.6	18.3	13.2%	89.9%
5%	8.4	1.4	17.6	17.9	6.6%	87.2%
10%	2.4	0.4	17.6	17.7	1.8%	82.6%

Table 6.1 – Estimated impact of reduced number of patient arrivals

The results in Table 6.1 show even a 1% or 2% reduced number of patient arrivals has a significant expected impact on the 'Time to bed'. A 10% reduction would eliminate most of the waiting time, although achieving 10% of reallocations is not likely. In interviews hospital staff estimate sufficient community resources and increased capacity at Parkwood could roughly reduce the number of patients at Inpatient Psychiatry by 10% to 25%, so any way a decrease in patient admissions to Inpatient Psychiatry can be structurally reduced will have positive impact on the waiting time for mental health patients.

6.2 INTERVENTION 2: REDUCING INPATIENT PSYCHIATRY SERVICE TIME

In this section the estimated impact of reducing the service time for all patients by 1%, 2%, 5%, and 10% is explored. As Table 6.2 shows, even a 1% or 2% decrease in service time can reduce the 'Time to bed' and average number of patients waiting quite significantly.

Service time	Time to bed (hrs)	Queue length	Service time (days)	LOS (days)	>8 in queue	Bed utilization
-	28.7	5.0	17.6	18.8	20.2%	91.8%
99%	22.5	3.9	17.4	18.4	16.6%	90.9%
98%	17.3	3.0	17.3	18.0	13.4%	90.0%
95%	8.1	1.4	16.7	17.1	6.7%	87.3%
90%	2.2	0.4	15.9	15.9	1.8%	82.7%

Table 6.2 – Estimated impact of % service time reduction

6.3 Intervention 3: No patients stay for longer than certain number of days

ALC patients seem to have a large impact on the available bed capacity at Inpatient Psychiatry. Approximately 10% of bed-days are used to accommodate ALC patients. The analysis in this section estimates the impact on the Inpatient Psychiatry performance if no patients would stay for more than *x* number of days.

Max. days	Time to bed (hrs)	Queue length	Service time (days)	LOS (days)	>8 in queue	Bed utilization
-	28.7	5.0	17.6	18.8	20.2%	91.8%
300	19.5	3.4	17.4	18.2	15.0%	90.5%
200	15.2	2.7	17.2	17.8	12.1%	89.7%
100	2.3	0.4	15.9	16.0	1.9%	82.9%
80	0.6	0.1	15.1	15.1	0.4%	78.6%
60	0.1	0.0	13.8	13.8	0.0%	71.9%

Table 6.3 – Estimated impact of limit on days in Inpatient Psychiatry

As Table 6.3 shows, if no patients would stay for longer than 300 days, there is already a significant decrease in 'Time to bed' compared to the first row (current situation). If no patients would stay longer than 100 days, the 'Time to bed' would drop by approximately 90%. The impact of long-stay patients on the waiting time of patients is quite significant.

6.4 Intervention 4: Increasing the Inpatient Psychiatry capacity

The sections above estimate the impact on 'Time to bed' if either the service time or the number of patients is changed. This section estimates the number of beds needed if the service times, ALC patients, and number of patient arrivals stay the same.

IP beds	Time to bed (hrs)	Queue length	Service time (days)	LOS (days)	>8 in queue	Bed utilization
80	28.7	5.0	17.6	18.8	20.2%	91.8%
82	15.0	2.6	17.6	18.2	11.8%	89.6%
84	8.1	1.4	17.6	17.9	6.7%	87.4%
86	4.4	0.8	17.6	17.8	3.7%	85.4%
88	2.4	0.4	17.6	17.7	2.0%	83.4%

Table 6.4 – Estimated number of beds needed in current situation

An estimated 4 to 6 extra beds in the current situation might alleviate the stress on the department a bit, however addition of beds is the current situation is quite costly. Keep in mind the waiting time estimates from the simulation model are optimistic (see Appendix H.2 – Simulation model validation). Investigating ways to reduce the number of patient arrivals or limiting their service time can also achieve similar reductions at presumably lower costs.

6.5 Analysis limitations

The results of the scenarios and interventions give a good indication of the effect the factors arrival rate, service time, and capacity have on the waiting time of Inpatient Psychiatry. However, some limitations exist. The simulation model givens a good indication, however it is optimistic with the waiting time estimates. No theoretical distribution could be fit to the service times, possibly because of multiple heterogeneous populations within the same data. This reduces the predictive capacity of the simulation model somewhat.

Additionally, a phenomenon 'suppressed demand' exists, meaning some patients now choose to not go to the hospital because of high waiting time. If the changes of previous sections are implemented, it is possible the waiting time does not reduce by as much as expected. This can happen because patients that previously did not go to the hospital, hear about the lower waiting times and do present to the hospital, increasing the patient arrivals and waiting times again. However, this does still mean more patients are helped compared to the old situation.

The biggest issue with the data is that data is recorded per department rather than per visit. The Inpatient Psychiatry data also does not specify whether the patient entered via the Emergency department or via GP referral and coordinated access, since admissions always go through CEPS. Visits in the Inpatient Psychiatry records were matched with ED visits based on the same anonymized patient number, where for each Inpatient Psychiatry visit a matching ED visit was searched for. The ED visit where the ED disposition timestamp was (nearly) the same as the IP registration timestamp is matched, and the waiting time is estimated from that.

For each calculation the data is checked for reliability and bad records filtered if necessary, which might change per type of calculation. In determining the number of patients that got an ED disposition decision, counting the records is enough. However, if the average waiting time from ED disposition to the time a patient leaves the ED needs to be determined, unreliable timestamps need to be filtered out. For more details on the data cleaning steps see Appendix I – Data cleaning.

6.6 Conclusions

Reducing the number of arrivals, reducing the service time, and increasing the capacity of Inpatient Psychiatry will all contribute to reducing the 'time to bed' for adult mental health patients. As the scenario and intervention analyses show, even relatively small improvements have significant impact on the waiting time.

Reducing the number of patient admissions and decreasing the service time by 1% or 2% have approximately the same impact, in both cases a decrease of 2% decreases the waiting time significantly. Increasing the number of beds by 4-6 likely decreases the waiting time as well, however adding beds is very expensive.

An interesting insight is the reduction of waiting time if no patients stay for longer than *x* number of days, which relates to the long stays of (ALC) patients. If no patients would ever stay for more than 100 days, the 'time to bed' will drop by approximately 90%.

7 CONCLUSION

The mental health patients going to Victoria hospital encounter significant waiting time, especially if they end up getting admitted to Inpatient Psychiatry. The inpatient department operates at 93% bed utilization which is quite high for a department with variable (non-elective) patients. Because of the high bed utilization and the variation inherent in the patient arrivals and service times, patients often need to wait a long time before they can enter a bed at Inpatient Psychiatry: on average 1.5 days (90th percentile 3.5 days).

Admitted patients waiting for an inpatient bed wait in the Emergency department, and reduce the available capacity of the Emergency department, as well as it being an unpleasant environment for the mental health patients, nor is it pleasant for other patients or staff.

Some problems are difficult for the hospital to solve by itself. Some patients cannot be discharged anywhere; a lack of community resources leads to patients waiting for discharge in inpatient beds. The impact of the quite extreme long length of stay of ALC patients leads to substantial use of bed capacity that cannot be used to help other patients. In a one-year period from 2015 – 2016, 10% of the bed days were used by ALC patients. Analysis in Chapter 6 shows that if no patients would stay for more than 100 days, an approximate 90% decrease of 'time to bed' can be achieved.

The hospital is already working on the ALC problem, a case manager is working to find suitable discharge options for patients, reducing the long stays. However, at a system level more resources might be needed outside Victoria hospital.

In case the number of beds or the ALC patients cannot be influenced, even a 1% or 2% decrease in arrival rate or service time lead to significant decrease of 'time to bed' for adult mental health patients. These options should not be overlooked, although

Adding additional beds can also reduce waiting time, but is a very expensive intervention.

In conclusion: any reduction of the number of patient admissions, the time they stay at Inpatient Psychiatry or adding additional beds will decrease the waiting time by reducing the 'time to bed'. This will also free capacity at the Emergency Department. Limiting the long stay of patients at Inpatient Psychiatry should be attempted as much as possible.

Further research

A few recommendations for further research opportunities are:

- Finding additional improvements in reducing the number of ALC days
- Consider a whole-system study of mental health facilities at the LHIN level
- Perform a more detailed process analysis at Inpatient Psychiatry to identify possible (administrative) inefficiencies and reducing the length of stay while improving quality of care
- Study the differences between PICU and regular patients to identify improvements
- Adding a unique visit id in the data recording, to allow for future patient flow analysis over multiple departments, which can possibly identify inefficiencies at the hospital level

The hospital is already working hard on finding suitable discharge options for ALC patients, but any additional improvements are welcome as they will reduce the waiting time for mental health patients.

The lack of capacity at community support and the Parkwood institute lead to more arrivals and higher service times at Victoria. Esensoy & Carter (2015) have created a quantitative model to look at patient flow at the LHIN level, including *acute hospital care*, *home and community care*, *rehabilitation and complex community care*, *long-term care homes* and *informal care*. Performing a study like this might be useful to help push for more capacity at facilities outside the hospital, reducing the number of ALC patients.

Since changing things outside the hospital will likely take a long time, any improvements that can be made to reduce the Inpatient Psychiatry service time – while maintaining or improving quality of care – should be investigated. A study looking at the processes of Inpatient Psychiatry might identify some inefficiencies that can be changed. This does not mean clinical processes need to be investigated necessarily, improvements to administrative processes without changes to patient care might also reduce service times and reduce waiting times, without impacting the quality of care (in fact, even improving it because of lower waiting times). (Moran, Jacobs, & Mason, 2016) associate higher emergency readmission rates with shorter length of stay in a study of mental health providers. A study on reducing service times should focus on finding inefficiencies, not simply suggest always discharging patients 1 day earlier, which likely worsens the quality of care.

A study on the PICU and non-PICU patients could also prove useful to find improvements. Currently the waiting time for a PICU bed is higher than for a regular bed at Inpatient Psychiatry, while the patients in need of a PICU bed are even less suited to wait for long times for a bed in the Emergency department. However, to study the PICU versus non-PICU additional data needs to be collected. Currently the waiting time for PICU and regular mental health patients is not separated, and no data is available on how long patients stay in a PICU bed.

Adding a unique visit identifier to the hospital data recording will be useful for future studies that need information over multiple departments. Focusing only on one department leads to local optimizations but can be very inefficient at the hospital level. In order to study the patient flow through the hospital and improving patient flow, waiting time and experience, a unique visit identifier is needed.

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APPENDIX

APPENDIX A – CALCULATIONS

page	Statement in text	calculation	result
3	180 ED arrivals per day	127,348 / 699 days	182.2
12	7.2% of ED patients MH flag	9,137 / 127,348	7.17%
12	13 mental health patient arrivals / day	182.2 * 0.0717	13.1
17	92.7% bed utilization	74.14 / 80	92.7%

APPENDIX B.1 – AVERAGE QUEUE LENGTH (ONLY PTS ADMITTED TO IP MH)

time of census	Average queue length (no. of patients)	Percentage of time over capacity (>8)
00:00	5.97	17.8%
01:00	6.13	20.1%
02:00	6.27	21.7%
03:00	6.42	23.0%
04:00	6.58	25.0%
05:00	6.71	26.3%
06:00	6.80	27.3%
07:00	6.87	28.1%
08:00	6.93	28.9%
09:00	6.96	28.9%
10:00	6.94	28.5%
11:00	6.80	26.8%
12:00	6.62	24.0%
13:00	6.32	18.9%
14:00	6.04	16.4%
15:00	5.71	13.8%
16:00	5.48	12.3%
17:00	5.41	10.9%
18:00	5.31	11.0%
19:00	5.32	10.9%
20:00	5.46	12.2%
21:00	5.60	13.8%
22:00	5.70	14.6%
23:00	5.82	16.0%
Average	**6.17**	**19.9%**

APPENDIX B.2 – AVERAGE NO. OF MH PTS IN THE ED (ALL MENTAL HEALTH PATIENTS)

time of census	Average IP queue length (n=2453)	non-IP queue length (n=4615)	Percentage of time combined use is over capacity (>8) (n=7068)	Combined
00:00	5.97	2.17	42.8%	8.14
01:00	6.13	2.13	44.9%	8.26
02:00	6.27	2.04	46.5%	8.31
03:00	6.42	1.95	46.2%	8.37
04:00	6.58	1.81	47.2%	8.39
05:00	6.71	1.90	48.0%	8.61
06:00	6.80	1.92	49.0%	8.72
07:00	6.87	1.90	50.0%	8.77
08:00	6.93	1.78	49.8%	8.71
09:00	6.96	1.75	49.7%	8.71
10:00	6.94	1.72	48.5%	8.66
11:00	6.80	1.78	47.4%	8.58
12:00	6.62	1.80	45.9%	8.42
13:00	6.32	1.90	44.2%	8.22
14:00	6.04	1.89	40.0%	7.93
15:00	5.71	1.97	36.5%	7.68
16:00	5.48	2.00	32.6%	7.48
17:00	5.41	2.08	35.2%	7.49
18:00	5.31	2.10	32.9%	7.41
19:00	5.32	2.10	34.5%	7.42
20:00	5.46	2.23	35.7%	7.69
21:00	5.60	2.20	37.0%	7.80
22:00	5.70	2.25	39.8%	7.95
23:00	5.82	2.27	42.8%	8.09
Average	**6.17**	**1.99**	**42.8%**	**8.16**

APPENDIX C – BOX PLOT INPATIENT PSYCHIATRY LENGTH OF STAYS

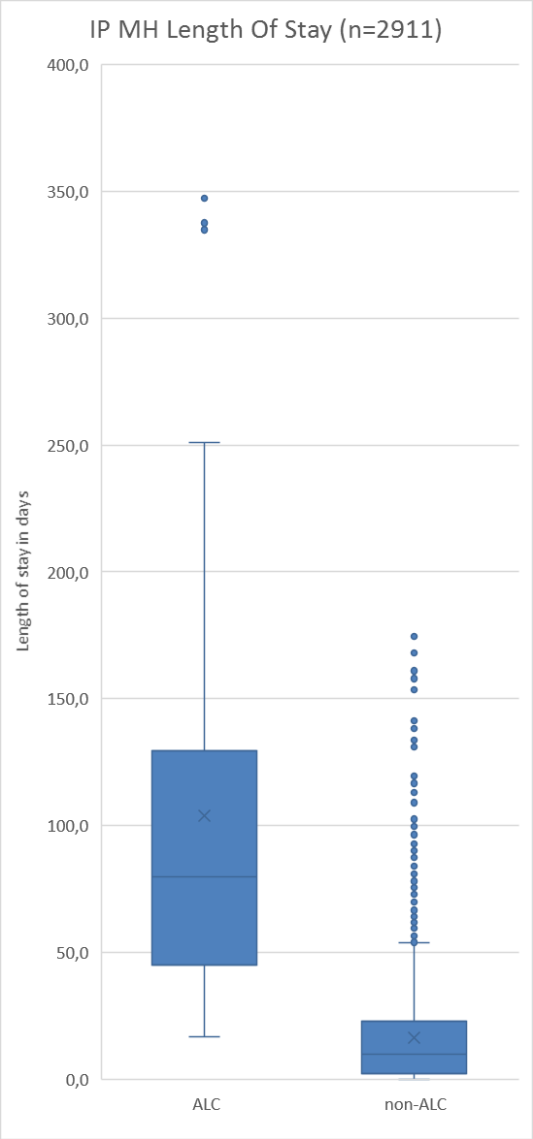


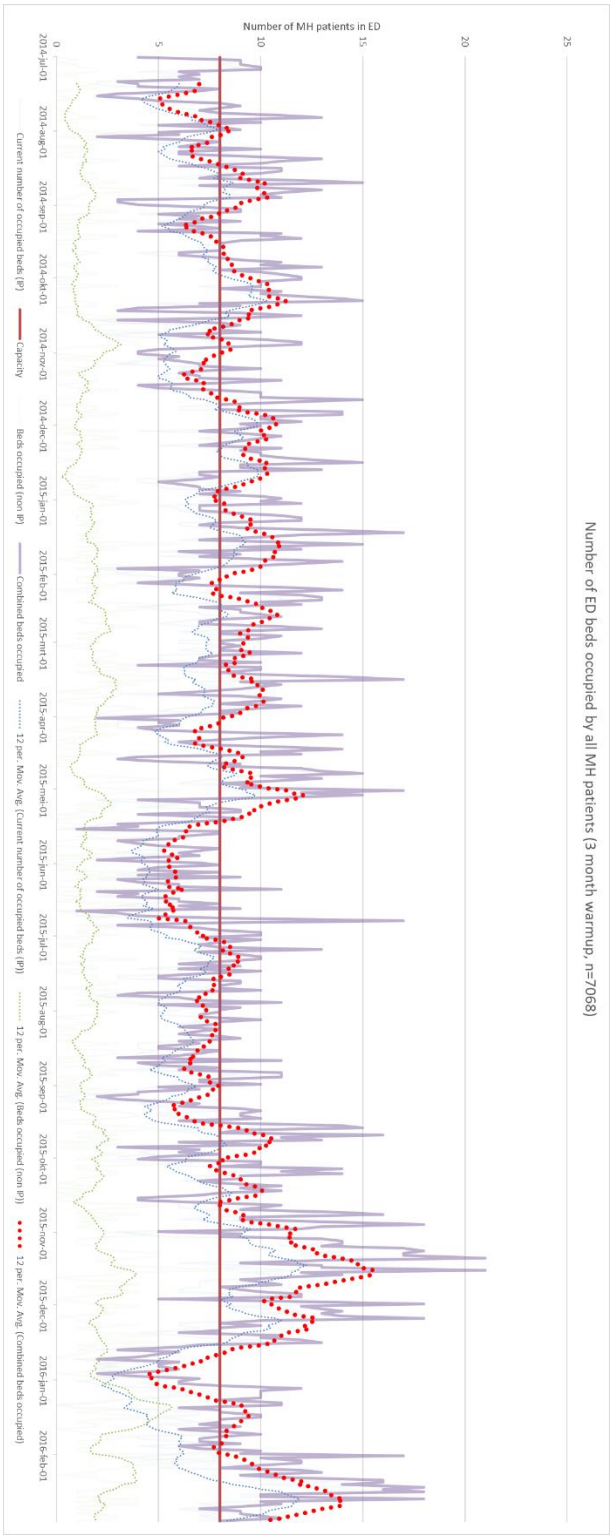
Figure 0.1 - Box plot of the differences between IP MH length of stay between ALC and non-ALC patients (Victoria hospital 2014 – 2016, n=2911)

The box plot in Figure 0.1 shows that the length of stay for ALC patients is longer than for non-ALC patients, as is expected. The length of stay for ALC patients can run quite high, the data from April 2014 – February 2016 included a few patients that stayed for almost an entire year.

Also noteworthy are the 'non-ALC' patients that stay for quite long times, even reaching 180 days length of stay in some cases. This matches with information from interviews, where hospital staff suspected ALC patients are underreported.

APPENDIX D – NUMBER OF MH PATIENTS IN THE ED (DAY-BY-DAY, JULY-2014 TO FEB-2016, 08:00 CENSUS)

The number of mental health patients present, both 'Only-ED' mental health patients that do not get admitted to IP MH (green line), the number of patients that are admitted to IP MH and are waiting for a bed (blue line), combined number (purple line) and the 12-week average (red-dotted line). Based on census taken at 08:00.



APPENDIX E – LITERATURE SEARCH

Strategy: search for term in Google Scholar, read abstract of first 30 results and select papers that are either relevant on the method used or are useful in general for the report. Also list what kind of unwanted subjects are found to improve the search term on the next iteration. Only papers that have been cited 5 times or more are selected as a basic quality filter.

Search term	Results	Removed based on abstract	Useful for in general	Useful for method	Wrong subjects
reducing inpatient psychiatry waiting time	32,000	28	2	0	Outpatient, clinical changes, wait time perception, triage, outside hospitals, financing strategy (US)
reduce psychiatr* boarding	17,100	29	1	0	Impact of, predictors, boarding schools, clinical changes
wait time analysis hospital inpatient psychiatry	30,900	29	1	0	Questionnaire design, patient satisfaction, police admission, drug screening
"waiting time analysis" AND "hospital" AND "mental health" OR "inpatient psychiatry"	12	10	0	2	Outpatient, patient satisfaction, pre-hospital interventions, emergency department, clinical change
"wait* time" AND "analysis" AND "hospital" AND "inpatient" OR "bed$"	1,350	24	0	5	Workload impact, forecasting arrivals, before & after, wait time from surveys, 1 double result, specific disease, ambulance diversion, meta study
"inpatient" AND "department" AND "bed$" AND -emergency AND "hospital" AND "wait" AND "time$" AND "analysis"	6,470	29	0	1	Cross-country bed utilization comparison, macro resource allocation, cost analysis, clinical method, patient satisfaction, case mix adjustment
reduc* wait* time analysis inpatient hospital department - "emergency department" - elective	18,200	30	0	0	Generic framework, before & after (lean), death costs, perceived quality, clinical method, elective

analysis inpatient psychiatry bed capacity	29,700	29	0	1	Comparison study, generic overview, clinical research, LOS predictors, revolving door
simulation model hospital alternate level of care ALC	17,200	26	3	1	Long term care facility, for-profit comparison, clinical study

Select papers based on a more detailed reading. For these papers, perform a forward search to include any new findings or related articles of interest.

Starting paper	Results	Removed	Useful for in general	Useful for method	Wrong subjects
A study of waiting and service costs of a multi-server queuing model in a specialist hospital Kembe e.a., 2012	20	20	-	-	Pharmacy staffing, e-marketplace, <5 citations
A system model of work flow in the patient room of hospital emergency department Wang e.a., 2013	20	19	1	-	Lung cancer detection, <5 citations
A Two-Time-Scale Approach to Time-Varying Queues in Hospital Inpatient Flow Management Dai and Shi, 2015	10	10	-	-	Double result, <5 citations
Dynamics of bed use in accommodating emergency admissions: stochastic simulation model Bagust e.a., 1999	454	22	3	5	ED overcrowding and mortality, hospital occupancy link with ED crowding, lean process redesign, clinical review, ambulance diversion, IC variability, impact of hospital restructuring, country comparison, patient mix
Hospital Variability in Emergency Department Length of Stay for Adult Patients	39	30	0	0	Clinical study, ED LOS comparison, comparison type of insurance (U.S.), substance abuse, predictors of frequent ED visits, <5 citations

Receiving Psychiatric Consultation: A Prospective Study Chang e.a., 2011					
Modeling and analysis of work flow and staffing level in a computed tomography division of University of Wisconsin Medical Foundation Wang e.a., 2012	188	24	2	4	Appointment scheduling, altering of patient flow
Modeling and Improving Emergency Department Systems using Discrete Event Simulation Duguay & Chetouane, 2007	188	-	-	-	Almost all citations the same as the paper by Wang et al, 2012, skipped
Models and Insights for Hospital Inpatient Operations: Time-Dependent ED Boarding Time Shi e.a., 2015	45	30	0	0	Appointment scheduling, ICU admission control, <5 citation papers
No room at the inn: overcrowding in Ontario's emergency departments Drummond, 2002	90	29	1	0	ED demand, ED costs of boarding, Australian ED attendance, influenza
Queueing for Healthcare Palvannan & Teow, 2012	30	-	-	-	<5 citations per paper
Smoothing inpatient discharges decreases emergency department congestion: a system dynamics	23	22	1	0	Modeling whole hospital, operating 24/7, admission smoothing multiple departments, Spanish, <5 citations

simulation model Wang e.a., 2010					

The resulting papers are read more in detail and those that are useful either for method used in hospital modeling or are useful in general to the report are retained.

APPENDIX F.1 – ONE DISTRIBUTION FOR ARRIVALS

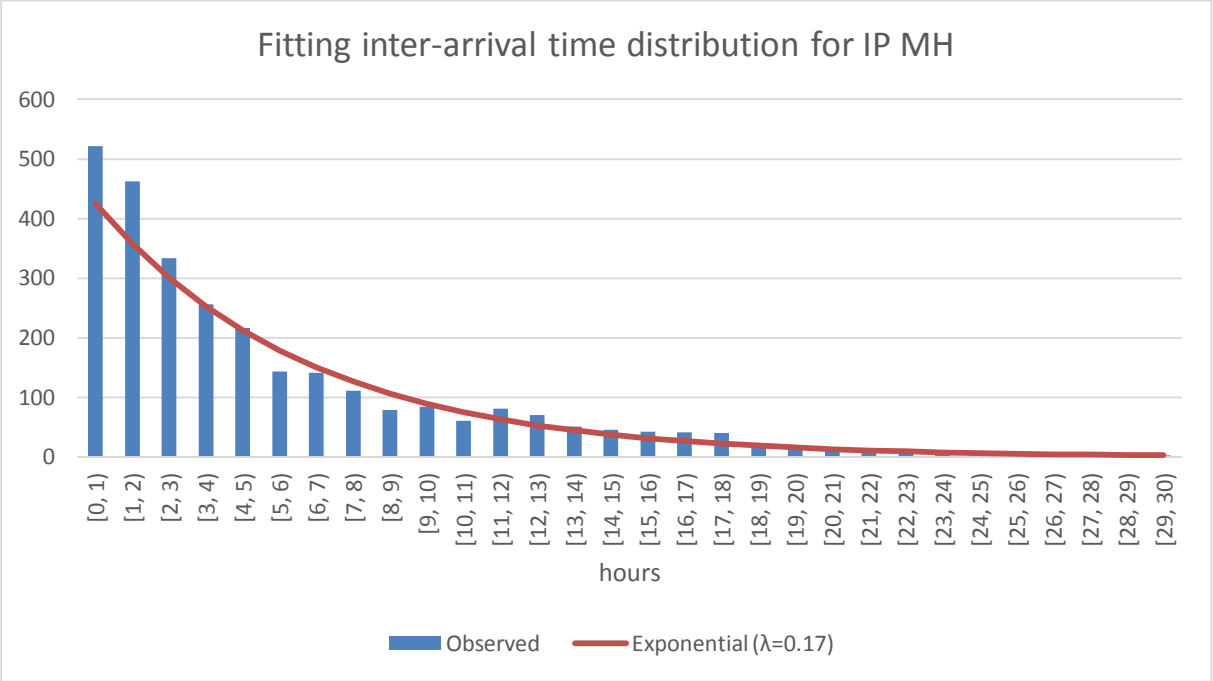


Figure 0.2 – Fit of exponential distribution to IP MH arrivals

The first step in fitting a distribution to the arrivals is to check if a distribution can accurately describe all arrivals. Both fitting an exponential and a gamma distribution are executed however the goodness of fit tests reject both distributions.

The exponential distribution with λ=0.17 gives a chi-squared error of 121.36, and the critical value (given an alpha of 0.05) is 37.28, so the distribution is rejected. For gamma distribution with parameters α=0.85 and β=6.77 the chi-squared error is 89.64, which is an improvement over the exponential distribution but still not a good fit.

Goodness of Fit Test

Distribution	AD	P
Normal	167,224	<0,005
3-Parameter Lognormal	9,224	*
2-Parameter Exponential	12,122	<0,010
3-Parameter Weibull	2,253	<0,005
Smallest Extreme Value	347,695	<0,010
Largest Extreme Value	84,133	<0,010
3-Parameter Gamma	3,055	*
Logistic	122,410	<0,005
3-Parameter Loglogistic	13,999	*

Figure 0.3 - Arrival distribution fitting with Minitab

As Figure 0.3 shows, with the statistical software Minitab all distributions fitted have a very low p-value, meaning they are not a good fit for the data. Conclusion is that the arrivals of patients to Inpatient Psychiatry cannot be fitted with a single distribution, a split of data per day or per hour might be necessary.

APPENDIX F.2 – ARRIVAL DISTRIBUTION PER DAY OF THE WEEK

The number of arrivals per day of the week differ, as shown in Table 0.1. For none of the days the exponential distribution provided a good fit when tested with an equal-probability goodness of fit test, with $\sqrt{n}$ number of bins, and an α of 0.05. For each day Minitab is also executed to fit distributions for individual days, but no suitable distributions were found.

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
n	444	503	487	434	435	300	308
λ (per hour)	0.165	0.205	0.202	0.192	0.174	0.153	0.124
Chi-squared	35.9	27	21.2	34.6	40.4	15.7	17.6
Critical value	10.9	11.6	11.6	10.9	10.9	8.0	8.7
Decision	Reject	Reject	Reject	Reject	Reject	Reject	Reject

Table 0.1 – Goodness of fit for exponential distribution to arrivals split per day of the week

Fitting per hour of the day rather than per day of the week might deliver better fitting distributions.

APPENDIX F.3 – ARRIVAL DISTRIBUTION PER HOUR OF DAY

Figure 0.4 shows the admissions per hour of the day for different days. Arrival rates are really similar during the night, however during the day larger differences show, with the biggest differences between weekdays and weekend days.

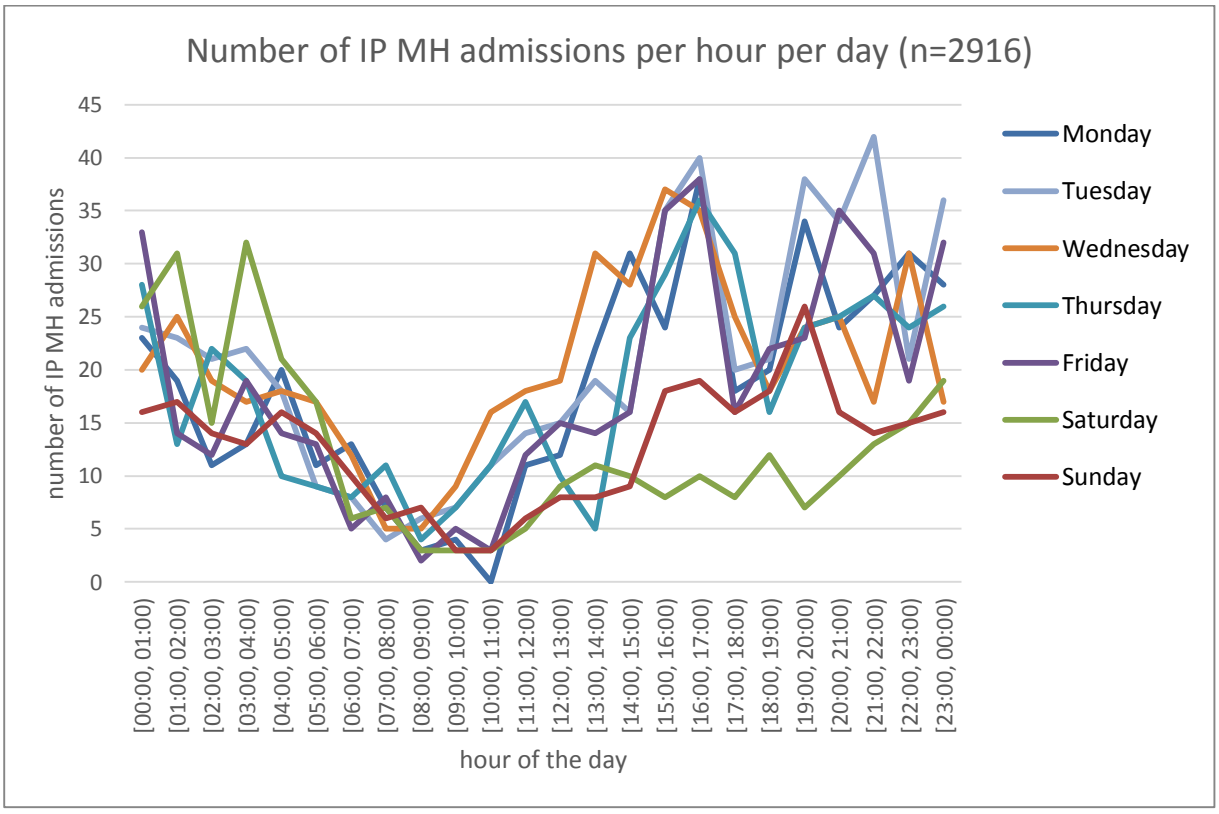


Figure 0.4 – IP MH admissions per day and per hour (Victoria hospital 2014-2016, n=2916)

begin	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
end	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
exponential fit	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no

Table 0.2 – Goodness of fit of exponential distribution to arrivals grouped by hour

The exponential distribution is also fitted per hour of the day, with all days grouped together. During the night, where the pattern of arrivals is quite similar this provides a good fit, however during the day the differences between days become too large, and a single per hour distribution does not provide a good fit.

This suggests arrivals are likely exponentially distributed, however the differences between days might be too large for a single distribution fit where days are grouped together.

APPENDIX F.4 – ARRIVAL DISTRIBUTION PER DAY AND PER HOUR

hour\day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
(0, 1]	0.23	0.24	0.21	0.28	0.33	0.26	0.16
(1, 2]	0.19	0.23	0.24	0.13	0.14	0.31	0.17
(2, 3]	0.12	0.21	0.20	0.22	0.13	0.16	0.14
(3, 4]	0.12	0.22	0.16	0.19	0.19	0.31	0.13
(4, 5]	0.20	0.18	0.18	0.10	0.14	0.21	0.16
(5, 6]	0.12	0.09	0.17	0.09	0.12	0.18	0.14
(6, 7]	0.12	0.08	0.12	0.10	0.06	0.05	0.10
(7, 8]	0.07	0.04	0.05	0.09	0.08	0.07	0.06
(8, 9]	0.03	0.06	0.05	0.04	0.01	0.03	0.07
(9, 10]	0.04	0.07	0.09	0.07	0.05	0.03	0.03
(10, 11]	0.00	0.11	0.16	0.12	0.06	0.03	0.03
(11, 12]	0.11	0.14	0.18	0.16	0.09	0.05	0.06
(12, 13]	0.12	0.15	0.20	0.11	0.15	0.09	0.08
(13, 14]	0.22	0.19	0.30	0.04	0.14	0.11	0.08
(14, 15]	0.32	0.16	0.28	0.23	0.17	0.10	0.09
(15, 16]	0.26	0.37	0.37	0.29	0.34	0.08	0.18
(16, 17]	0.36	0.38	0.36	0.37	0.38	0.10	0.19
(17, 18]	0.19	0.20	0.25	0.30	0.16	0.08	0.16
(18, 19]	0.18	0.21	0.18	0.17	0.22	0.12	0.18
(19, 20]	0.34	0.38	0.23	0.24	0.24	0.07	0.27
(20, 21]	0.24	0.34	0.25	0.24	0.35	0.11	0.15
(21, 22]	0.27	0.42	0.18	0.29	0.32	0.13	0.14
(22, 23]	0.32	0.22	0.30	0.23	0.18	0.14	0.16
(23, 24]	0.27	0.35	0.17	0.25	0.31	0.19	0.15

Table 0.3 - Average number of IP MH arrivals per day per hour (Victoria hospital 2014-2016, n=2916)

The input parameters for the exponential distribution: the average number of patient arrivals per day and per hour. This is used to describe the arrivals in the mathematical model.

APPENDIX G – SERVICE TIME THEORETICAL DISTRIBUTION FITTING

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	140,942	<0,005	
Box-Cox Transformation	2,460	<0,005	
Lognormal	31,880	<0,005	
3-Parameter Lognormal	8,709	*	0,000
Exponential	3,803	<0,003	
2-Parameter Exponential	4,931	<0,010	0,000
Weibull	2,486	<0,010	
3-Parameter Weibull	3,269	<0,005	0,000
Smallest Extreme Value	421,531	<0,010	
Largest Extreme Value	39,158	<0,010	
Gamma	2,287	<0,005	
3-Parameter Gamma	2,961	*	0,000
Logistic	69,754	<0,005	
Loglogistic	18,825	<0,005	
3-Parameter Loglogistic	13,246	*	0,000

Figure 0.5 – Fit of theoretical distributions to IP service time (n=2583)

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	55,463	<0,005	
Box-Cox Transformation	4,871	<0,005	
Lognormal	33,704	<0,005	
3-Parameter Lognormal	11,994	*	0,000
Exponential	11,777	<0,003	
2-Parameter Exponential	9,402	<0,010	0,000
Weibull	4,392	<0,010	
3-Parameter Weibull	5,296	<0,005	0,000
Smallest Extreme Value	106,161	<0,010	
Largest Extreme Value	22,463	<0,010	
Gamma	5,131	<0,005	
3-Parameter Gamma	6,402	*	0,000
Logistic	43,729	<0,005	
Loglogistic	23,897	<0,005	
3-Parameter Loglogistic	16,408	*	0,000

Figure 0.6 – Fit of theoretical distributions to IP service time, filtered times below 0.25 days and above 60 days (n=1986)

For the mathematical model we try to fit a theoretical distribution to the service time. Figure 0.5 shows the goodness of fit tests for a number of distributions fitted to the Inpatient Psychiatry service times. Only strict ED – IP MH matches were used. No distribution comes close to a good fit.

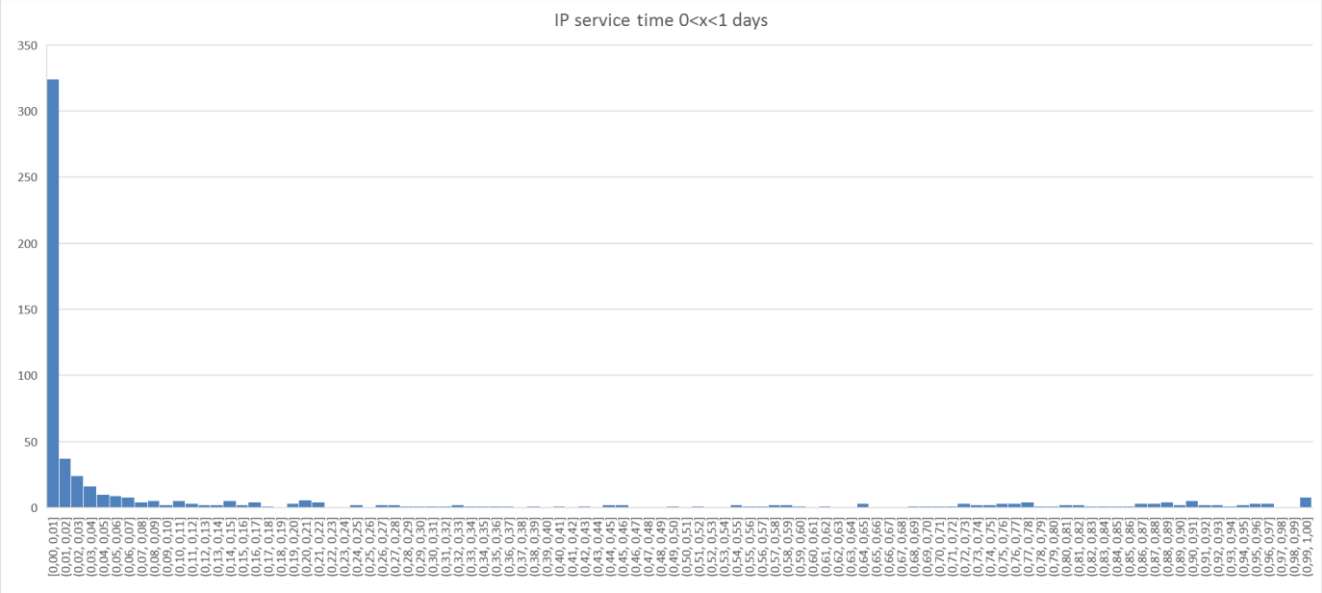


Figure 0.7 – Detailed overview IP service times between 0 and 1 days (Victoria hospital 2014-2016, n=583)

Figure 0.7 shows the histogram of IP service times between 0 and 1 days, in steps of 0.01 days (14.4 minutes). A very high number of patients (~325) had a service time between 0 and 14.4 *minutes*. This might make it impossible to fit a distribution to, so we only selected service times of longer than 0.25 days (6 hours) and less than 60 days (since ALC patient service times distort the distribution as well). Even with these outliers removed from the data, no distributions fit, as Figure 0.6 and Figure 0.8 show. Perhaps there is a mixture of two or more heterogeneous populations in the service times, or service times are irregular for another reason. The conclusion is the service times for Inpatient Psychiatry cannot be fitted to a theoretical distribution, an empirical distribution or direct data is needed in the model.

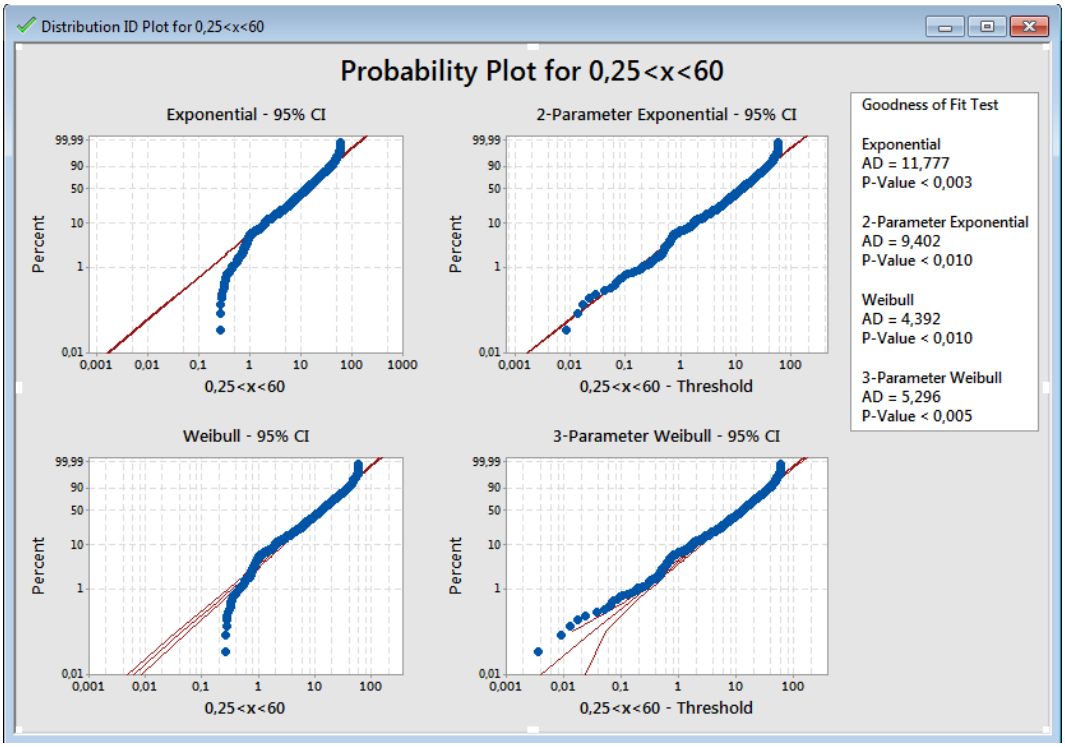


Figure 0.8 – PP-plot for service time fitting, service times below 0,25 days and above 60 days excluded

APPENDIX H.1 – SIMULATION MODEL DETAILS

The simulation model described in Chapter 5 is implemented in Plant Simulation.

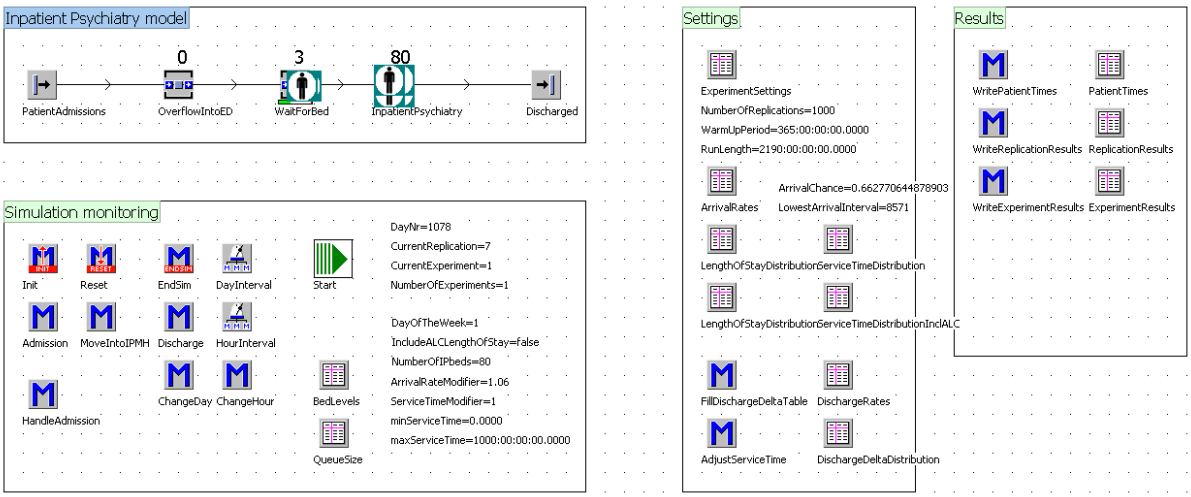


Figure 0.9 – Overview of the simulation model in Plant Simulation

The section 'Inpatient Psychiatry model' has the arrival object (PatientAdmissions), one unlimited waiting room (OverflowIntoEd) and one limited waiting room (WaitForBed) with 8 spots. The waiting room split is only in the model to make performance measurement easier, functionally they are equal to one queue with infinite capacity. Inpatient Psychiatry is a multi-server station. When patients have been at the Inpatient Psychiatry station for the duration of their service time they are discharged.

The section 'Settings' houses the input distributions. Arrival rates has the inter-arrival times for each day and each hour, and the correct arrival rate is applied at the right time. The arrivals are modeled as exponentially distributed arrivals, the lowest (non-zero) inter-arrival time is taken as the base rate, and depending on the day and hour, 'ArrivalChance' is modified to correct the high arrival rate to the current arrival rate (see 'Thinning', 8.6.2 in Law (2015)).

Two empirical service time distributions are loaded into the model, one with the distribution including the IP MH service time of all patients, one without the ALC patients' service times. Per experiment the choice for either service time distribution can be made. When a patient is created a service time for that patient is determined from the empirical service time distribution.

Similar to the arrivals, the number of discharges changes per day and per hour. Most discharges happen between 10:00 and approximately 19:00, which reduces the window in which patients will leave, which also increases the occupancy rates during certain parts of the day.

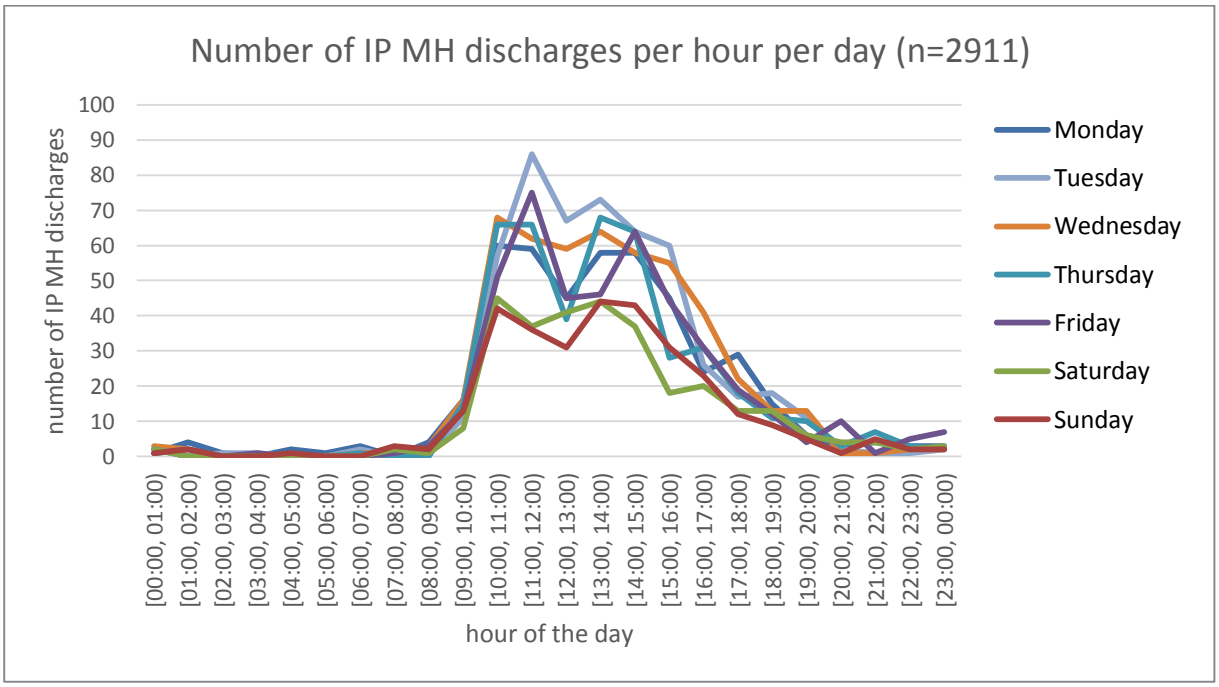


Figure 0.10 – IP MH discharges per day per hour (Victoria hospital 2014-2016, n=2911)

The discharge rates are applied at the moment a patient leaves the queue and is about to enter the service time determined for the patient is modified a bit. A window of 12 hours before to 12 hours after the original end time for that patient the discharge rates are filled to a table, and it is drawn from as an empirical distribution. The patient discharge times get adjusted to the realistic discharge moments which creates a more realistic result. Because a window of -12 hours to +12 hours is picked the average service times will stay the same. Checks are in place to prevent negative service times.

The table 'ExperimentSettings' contains the experiments to be performed and the settings for those experiments. The settings are: Number of IP beds (integer), Include ALC service times (Boolean), Arrival rate modifier (real), Service time modifier (real), minimal service time (time) and maximum service time (time).

Each experiment runs a number of times (replications) because computer simulation is a stochastic process, and multiple runs are needed to present statistically significant results. Using Welch' graphical method the warm-up length is set to 365 days. As Figure 0.11 shows, under default settings the first time all beds are occupied is around 200 days. Since the simulation model is relatively quick to run, the warmup length is rounded up to 365 days, which certainly provides enough time for the system to reach a steady state.

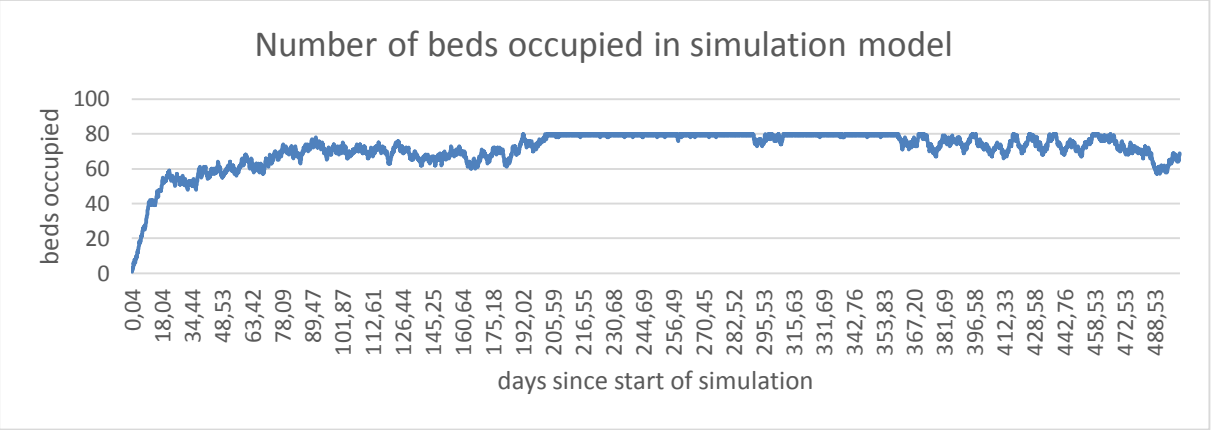


Figure 0.11 – Number of beds occupied over time in simulation model

The run length per replication is 2190 days (6 years), so effectively each replication produces 5 years of usable data. The output data is collected per replication, and is used to determine how many replications are needed to produce statistically significant results for each performance measure, where the relative error is less than 5%. For the average queue length, 949 replications are needed (see Figure 0.12 – Relative error of the queue length for certain number of replications). To be safe under other experiment settings the number of replications per experiment is set to 1000.

Queue length	n	Time to b	sample var	freedoms	t value	relative error
7,83	946	4,99	12,4385	945	1,962477	0,05
4,50	947	4,99	12,4256	946	1,962475	0,05
12,49	948	5,00	12,47185	947	1,962472	0,05
5,18	949	5,00	12,45873	948	1,96247	0,04
2,93	950	5,00	12,4501	949	1,962467	0,04
1,35	951	4,99	12,45099	950	1,962464	0,04
3,25	952	4,99	12,44109	951	1,962462	0,04

Figure 0.12 – Relative error of the queue length for certain number of replications

APPENDIX H.2 – SIMULATION MODEL VALIDATION

The simulation model is executed with the settings of the current situation: 80 beds, service times based on the empirical distribution including ALC patients.

	TimeToBed	QueueLength	ServiceTime	LengthOfStay	>8 in queue	Utilization
Simulation	28.7	5.0	17.6	18.8	20.2%	91.8%
Actual	36.2	6.2	17.3	17.7	19.9%	92.7%

Table 0.4 – Comparison of actual values with simulation model output

As Table 0.4 shows, there are some discrepancies with the model, namely the simulation model is optimistic in estimation of the 'TimeToBed' and queue length, and somewhat pessimistic in the length of stay. For service time, the percentage of time more than 8 patients wait for a bed and utilization rate it is very close to historical values.

For the purpose of this study the model is accurate enough to give an indication of the performance of scenarios and interventions.

APPENDIX I – DATA CLEANING

Data cleaning is performed differently per calculation. For calculations about number of patients no filtering is applied. For calculation where time differences are important (e.g. average waiting time) bad timestamps are filtered out. Based on information from the hospital, 00:00 timestamps are filtered out since 00:00 is recorded in the system when only a date was written down and no time was given. The overview of 00:00 timestamps per data column.

- For ED registration (N.Reg.DT) **14** occurrences
- For ED triage (N.Triage.DT) **24** occurrences
- For ED PIA (N.PIA.DT) **0** occurrences
- For CEPS request DT (N.Consult_1_ReqDT) **106** occurrences
- For CEPS consult DT (N.Consult_1_ArrivalDT) **12** occurrences
- For ED disposition (N.Disposition.DT) **0** occurrences
- For ED left (N.Left.ED.DT) **0** occurrences
- For IP registration (IP.Registration_Dt_Tm) **0** occurrences
- For IP discharge (IP.Discharge_Dt_Tm) **0** occurrences

Additionally, timestamps where an obvious input error was made are ignored (off by 1 year, month or day).

The matches between Inpatient Psychiatry visits and Emergency department visits were made manually since no indicator existed in the database on where patients in Inpatient Psychiatry came from, since all patients get admitted through CEPS.

The matches are made by looping through every Inpatient Psychiatry visit, then for that visit look through the ED visits with the same patient ID. Then from those options select the ED visit with the lowest absolute difference between Inpatient registration time and ED disposition time. Based on recommendations of the hospital, any matches where the time difference between the IP registration timestamp and ED disposition timestamp is greater than 12 hours are ignored. These data cleaning steps combined give the most accurate use of the data.