Towards a lean blood testing process in Campbelltown hospital

Campbelltown hospital, New South Wales, Australia

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Management summary

Introduction

Campbelltown hospital in Australia is one of many hospitals that experience overcrowding issues on the emergency department. These overcrowding issues result in long waiting times for health services at the ED. Expanding the capacity is very expensive, this is the reason that the University of Western Sydney (UWS) was invited to do research to improve the efficiency of the existing capacity. Interviews with important stakeholders indicated that test results from the pathology department were an important source of delay.

Problem description

This is a preliminary study of a large research project of UWS that will focus on multi-level performance innovations. This preliminary study aims to get insight in the process of pathology testing and the interaction between the Emergency Department(ED) and pathology. Based on these insights we indicate avoidable activities and make suggestions for possible interventions. The process of pathology testing starts from the moment a request for one or more pathology tests is submitted by a doctor from the ED and stops when the results are returned to the doctor.

Approach

The goal is to get an overview of the process and identify avoidable activities, for which we suggest interventions. For this process we used the chandelier model (Sambeek, 2005). To identify the avoidable activities we performed a qualitative research, which consists of observations and interviews. The potential avoidable activities are tested on the relevance of avoiding the activity and whether an activity can be (partly) avoided. We suggest possible interventions to challenge the root causes of the avoidable activities so that the avoidable activities can be reduced or even totally avoided.

Results

The causes for the avoidable activities can be categorized into 3 main causes:

- Planning: the planning of ward rounds and the unpredictability of outpatients cause an uneven demand for the pathology department.
- Communication: excessive telephone communication and inappropriate use of communication systems cause time losses.
- Logistics: the sense of time pressure causes an inefficient allocation of samples.

Conclusions

By influencing the causes with relatively simple adaptations the process of blood testing can be improved. To positively affect the causes we developed the following interventions:

- Reduction of variability via planning: by planning of ward rounds and outpatient arrival, the number of tests over time can be more equal and in cases where this is not possible, the planning of resources can be optimized to reduce the influence of variability.
- Proper use of priority system: doctors and nurses should be explained what the priority level imply and the pathology staff should get instructions how to use the priority system.
- Training ED staff: ED staff should be trained how to optimally supply pathology.

- Better use of communication tools ED: agreement between ED and pathology about the way of communicating (abnormal) test results.
- Alignment of goals: the expectations of ED and the goals of pathology about turnaround time for tests and the percentage of tests that should be within the maximal time frame should be aligned.

Recommendations

We recommend to quantify the activities by measuring the time spent by the lab staff so an estimation of time to be saved can be given. We recommend to measure the effect of the interventions using the KPIs we proposed in this report (§2.3.2). We also recommend to further research the demand for pathology services and perform a simulation study for operating hours and machine allocation over the different departments and hospitals of the SWAPS area.

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Abbreviations and definition of terms

NSW	New South Wales
SSWASH	Sydney South West Area Health Service
SWAPS	South West Area Pathology Service
ED	Emergency Department
Camden	Camden hospital, a small hospital without pathology department
PowerChart	One of the hospital IT systems, used to request pathology tests
PoC	Point of Care, two pathology machines deployed at the ED
Outpatient	Patients from outside referral
EAP	Emergency Admission Performance
Lab staff	The collective of lab technicians and collectors from the pathology department
Avoidable activity	An activity that should partly or completely removed from the activities performed by a certain function

Preface

This is the report of my graduation project of the bachelor degree in Industrial Engineering & Management of University of Twente. After finishing all my bachelor courses it was time to look for an assignment to finish the bachelor degree. I was inspired by many friends being abroad and a course about computer simulation that was used to evaluate staffing alternatives in a hospital. I started looking for an assignment in an English speaking country so I could improve my English speaking and writing as well. Thanks to Jelle Kooij I got in contact with Anneke Fitzgerald in Australia.

I was welcome to assist in a research from the University of Western Sydney for about 13 weeks. During this time I worked on a preliminary research for the Australian Research Council (ARC) Linkage project, with the title 'Multi-Level Performance Innovations: Emergency Department, Pathology Laboratory & Pathology Network'.

I had an office on Campbelltown campus and also spent several days in Parramatta, where there is another campus of UWS. Everywhere I came I was welcomed and invited for all sorts of events. One of my invitations was for the writing circle of PhD students, who helped me a lot in setting up my research and report.

I would like to thank Kate for keeping me focused on the goals, and for her flexibility to help me when the simulation study did not work out the way we had planned. I would like to thank Terry for taking me to Parramatta and for sparring with me about how to improve my research.

After work, Anneke's kids Chris and Kim took me to Sydney and all other nice places in the region. I would like to thank Chris for the amazing road trips to Canberra, Tocumwal and Melbourne and introduction to all his friends. I thank Kim for making me feel like part of the family and the hours of driving me around with great music.

My period in Australia was one big learning experience and above all an adventure. I would like to thank Anneke for sharing this experiences and adventure. She was not only the one who made my trip to Australia possible, she was also the one that made sure that I had an amazing Aussie experience. I was welcome to stay at her place, even when she was away to Holland, Turkey and Estonia. I also want to thank her for the evenings she spent on explaining me everything I wanted to know about Australia and especially the health care system.

Anneke has decided to leave the UWS, and move to the Gold Coast to make a new start. I wish her and Kim an amazing time and I hope to visit them as soon as possible. I also hope that Anneke gets the opportunity from her new university to continue to be hospitable, so other students can have the same wonderful experience that I had.

Finally I thank Erwin for inspirational conversations and helpful input to this report.

Sjaak Mulder

Enschede, February 2012

Chapter 1: Introduction

There is increased demand in Emergency Departments (EDs) within Australian hospitals, due to the growing and ageing population. This increasing demand results in overcrowding issues and long waiting times for the EDs (Booz, Allen, & Hamilton, 2007).

This study focuses on Campbelltown hospital, a public hospital situated in the southwest Sydney area. It is one of the hospitals that experience a lot of pressure on their Emergency Department, despite an earlier attempt in a previous study by (Fitzgerald et al., 2009) to solve the problem of bed blocking. Bed blocking or access block as it is called in Australia means that patients are waiting after having completed Emergency Department care. Reducing the access block in ED was done by improving the performance of the imaging department.

Because demand is still rising and increase in capacity is very expensive, University of Western Sydney was invited to do a follow up research project to increase the efficiency of the existing capacity. Interviews that were held with stakeholders after the previous study indicated that in addition to the results from the imaging department, the test results from the pathology department are also a source of delay.

Section 1.1 gives a description of the research environment to provide some understanding about the way the Australian health care system and Campbelltown hospital are organized. Section 1.2 provides a detailed description of the problem situation, which will lead to the research goals and research questions in section 1.3. Section 1.4 and 1.5 give a brief explanation of the methodology and limitations of this research.

1.1 Research environment

To understand the organization of an Australian hospital, a general understanding of the organization of health care and higher level policies in Australia is needed. Sections 1.1.1 and 1.1.2 provide a description of the Australian health care system and the Sydney South West Area Health Service (SSWAHS), of which Campbelltown hospital is a division. Section 1.1.3 gives an overview of Campbelltown hospital itself and the involved departments.

1.1.1 The two-tiered Australian Health Care System

Australia is a country of extremes; it is the largest island but also the smallest continent of the world and with a population of only 22 million people it is very thinly populated. With 89% of this population living in urban areas it is one of the most urbanized countries in the world. The cities are mostly located along the eastern coast and the southeastern corner of the continent. The population grew by 2.1% between 2007-2008 and 2008-2009, with 35% natural increase and 65% due to net overseas migration. The life expectation of an Australian is very high, with an expectation of 79.2 years for men and 83.7 years for women. The population is ageing; 3 million people were aged above 65 in 2010 and this will increase to an approximate 8.1 million by 2050. That means an increase from 13.5% to 22.7% of the total population (WHO, 2011).

Australia's commonwealth was formed in 1901 when the six Australian colonies agreed to The Australian Constitution, creating a Federal System of Government. The responsibilities of the Federal Government include foreign relations and trade, defense and immigration. In addition to the Federal Government, there are six States and two Territories, which have their own Government of State or Territory. Figure 1 shows a map of Australia and the segmentation of the States and Territories. The organization of the public health system is a partnership between the Federal, State and Territory Governments. The Federal Government is mostly entrusted with policy making, research and regulations that are nationwide, while the States and Territories are mainly responsible for the delivery and management of public health services, and the regulation of private hospitals (WHO, 2011).

Figure 1: Map of Australia (BBFA, 2008)

The Australian health system is very complex because of its combination of public and private provided health care. Figure 2 shows this combined arrangement, known as the two-tiered system. The reason for this system is to give universal access to health care with Medicare but also allow the choice for the private sector. Medicare is a compulsory insurance system funded by general taxation revenue. The working of Medicare is threefold:

- Providing funding to States and Territories to assist them in providing access to free public hospital services.
- Subsidization of a wide range of prescription medications supplied by community pharmacies.
- Providing consumers access to privately provided medical services and may include co-payments by users where the cost of services is not fully covered by the rebate.

The Australian government also funds a system of private health insurance rebates that subsidize the cost of premiums for private health insurers. In this way, a patient may choose to go to a free hospital/practice or go to a private hospital/practice where an extra fee can be charged that the patient or his insurance have to pay (WHO, 2011).

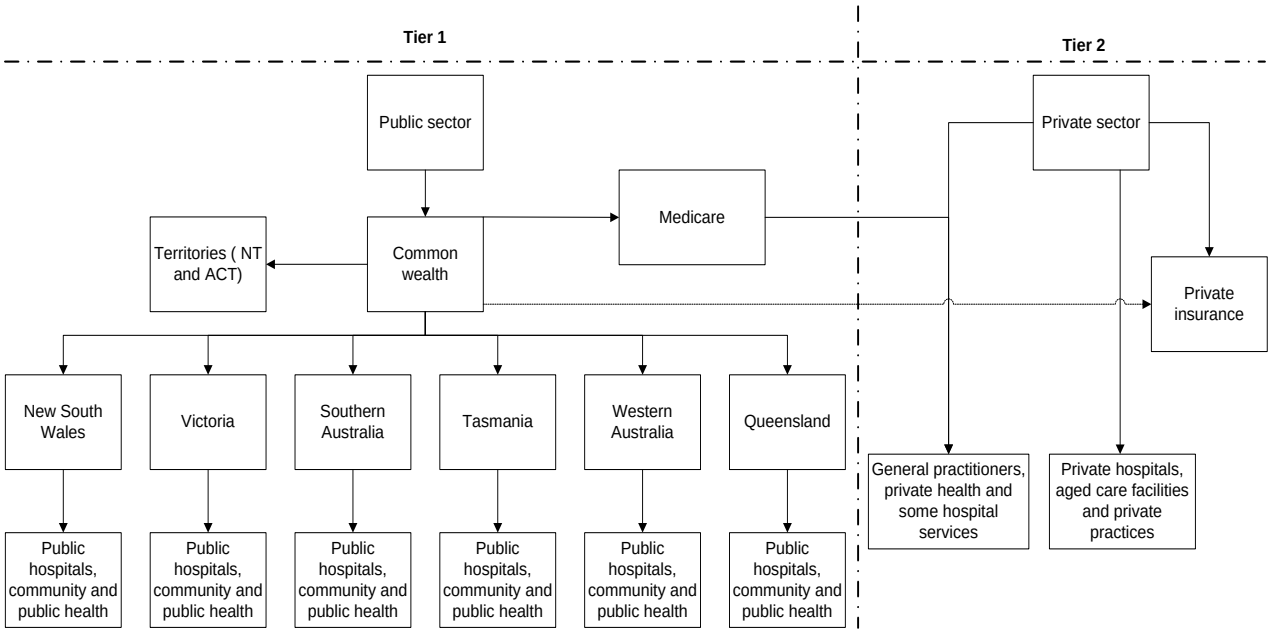


Figure 2: The two-tiered Australian health care system

1.1.2 Sydney South West Area Health Service

Campbelltown hospital, just like 16 other hospitals and other facilities, is part of the Sydney South West Area Health Service (SSWAHS), which is the coordinating organization for the region for South West Sydney. This health service area was the most populated in New South Wales (NSW), with a residential population of about 1.34 million residents in 2006. Within the area of 6,380 square kilometers covered by SSWAHS there is a lot of substantial new land release for residential development and medium density urban infill, meaning that this area is also one of the fastest growing regions in the State. The population is predicted to increase by 16% over the next ten years, which would result in a population of already 1.5 million in 2016 (SSWAHS, 2010).

In addition to the area of SSWAHS being the largest region and one of the fastest growing regions of the State, it is also the most ethnically diversified area of Australia and has some of the most disadvantaged communities of NSW. Nine suburbs in the area are among the 30 most disadvantaged suburbs of the state and in the 15 most disadvantaged suburbs in metropolitan Sydney (SSWAHS, 2010).

The figures for the collective EDs follow the growing trends of the State's population. During the last years the ED attendance grew by 2.5 percent per year, which is illustrated in figure 3 (NSW Department of health, 2008, 2009,2010).

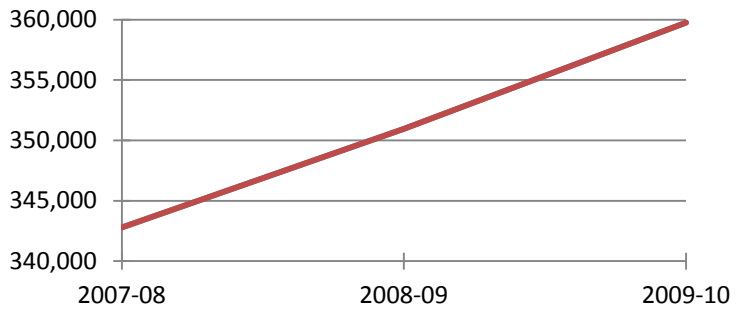


Figure 3: Growing ED Attendances in the area of SSWAHS (NSW Department of health, 2008, 2009,2010)

1.1.3 Campbelltown Hospital

To serve the community of Macarthur there are two public hospitals; Campbelltown and Camden, co-ordinated through Campbelltown hospital. The hospitals have a wide range of departments and services like for instance cardiology, intensive care, emergency, pathology, radiology and surgery (SSWAHS, 2008). Campbelltown hospital has around 360 beds and 1200 equivalent full time (EFT) staff. The number of patients that admitted during the financial year 2008-09 was approximately 28,000, while Camden is a much smaller facility without an ED and approximately 2,500 admissions during 2008-09 (NSW Health, 2010).

The following two paragraphs describe the departments that are the scope of this research, namely the **emergency department** that has overcrowding issues and the **pathology department**, which has been indicated by stakeholders as a major barrier to patient flow.

Emergency Department

The Emergency Department of Campbelltown hospital is one of the largest in the Sydney South West area. While the average increase in emergency attendances in the area was 2.5 percent per year, the ED attendances at Campbelltown hospital rose by well over 3.5% between 2008 and 2009, from 47,191 to 48,868. The Emergency Admission Performance (EAP) was 60 percent in 2008-09, which was by far the lowest of the region. This indicator shows that 60 percent of the patients are transferred from the ED to an inpatient ward within 8 hours (NSW Health, 2010).

The Emergency Department has different sections for patients with a different triage category. The triage categories range from 1, which is very urgent, to 5 for patients that have a symptom that does not need immediate medical treatment. The most urgent patients are sent to resuscitation or acute, less urgent patients are admitted to sub-acute and patients from category 4 or 5 can be sent to the urgent care centre.

Pathology Department

The pathology department is a service department to the other departments within the hospital, including the Emergency Department. This department diagnoses medical issues based on the laboratory analysis of bodily fluids such as blood and urine. There are many tests that can be performed on those fluids that can help doctors to make a proper diagnose.

The pathology department of Campbelltown hospital is part of a region wide network, South Western Area Pathology Service (SWAPS). There are twelve institutes in this network of which Liverpool Hospital is the largest one. Some of the institutes do not have a pathology department, like Camden hospital that sends all its tests Campbelltown hospital. In the area there are also some institutes that cannot perform all the existing tests, such as Campbelltown that sends some tests to Liverpool hospital. Liverpool hospital is also the place where all the test materials and results are stored for a month after the tests are completed. Figure 4 shows an overview of the SWAPS area that is relevant for the Campbelltown pathology department.

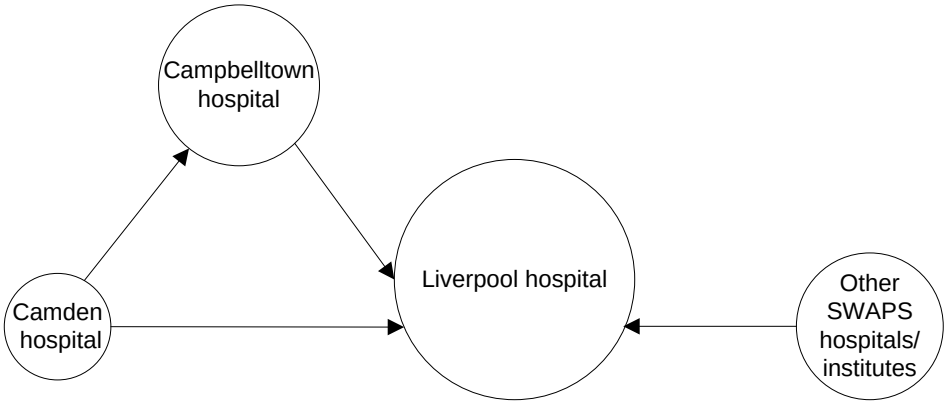


Figure 4: SWAPS overview

1.2 Research problem

By describing the research environment a large part of the problem has already been revealed. The number of ED attendances is rising and the ED time target of an EAP above 80 percent is not being met (Eager, Masso, Robert, & Bate, 2008). Despite many attempts to solve these problems there are still lengthy waiting periods for health services at the ED. To solve this problem we have to know what the causes for this problem are, in particular we are searching for a cause that has the potential to be minimized or eliminated, and by doing so will help to solve the problem.

The starting problem is the lengthy delay for receiving health service at the ED that many patients experience. There is a growing demand but patients cannot enter the ED because all beds are occupied. When a patient occupies a bed in the ED for more than eight hours this is called access block and the limited capacity of hospital EDs is evidenced by these access blocks (Fitzgerald et al., 2009).

Access block is primarily caused by disparity between the supply of and demand for emergency services. The rising demand is due to:

- *Changing patient demographics*. The population is ageing and growing. The population in NSW is growing with an average of 0.8% per year. The average age of patients attending the ED has increased over time, in line with the general ageing of population (Booz, Allen, & Hamilton, 2007; Australian Bureau of Statistics, 2008).
- *Decrease in private hospital ED capacity.* The number of private hospitals providing ED services over the past two years has fallen by half. The patients that were attending private EDs may now been diverted into public EDs (Booz, Allen, & Hamilton, 2007).
- *Increasing self referral to EDs by patients*. While the prices for general practitioners are rising and their accessibility is decreasing, patients are informed better about their health and have internet access, so therefore are presenting to ED departments more frequently (Booz, Allen, & Hamilton, 2007).

While the demand is rising, the capacity of EDs is limited by access block. Patients are staying a long time at the ED occupying beds. People can leave the ED in three ways: first, if there is no need for the patient to stay in the hospital he or she can be sent home; second, when the diagnosis is certain and the patient needs to stay in the hospital the patient can be sent to the department that best fits his or her needs; and third, the patient may die during their stay in the ED. The cause of the long waiting times is a combination of the policy that patients will only be sent to another department or home when the diagnosis is certain.

The problem bundle in figure 5 gives a schematic overview of the causes that form the basis of the problem. To solve the problem of the long waiting times, one or more causes on the left hand side of the figure should be (partly) solved. However, the causes that are colored in red cannot be solved because we cannot influence the growing demand and the nationwide policy to only transfer patients whose diagnosis is certain. Evaluation of each of the causes results in only one cause that is both a solution for the problem and is suitable to be influenced, namely the long waiting times for test results.

Previous research has been done to improve the efficiency of the imaging department, which resulted in an eminent increase in patient flow (Fitzgerald et al. 2009). Following recent interviews with ED staff and hospital management there is still access block experienced and the ED clinicians have identified pathology as a major area for this access block. The ED clinicians indicate that only 20-30% of the results are available within 30 minutes, while this should be 70% in the desired situation. A 100% is not possible because not all the tests can be performed by the pathology department at Campbelltown and need to be tested at Liverpool which is 25 kilometers away. The desired situation of 70% is set as goal because this is the percentage of tests that can be performed at Campbelltown hospital.

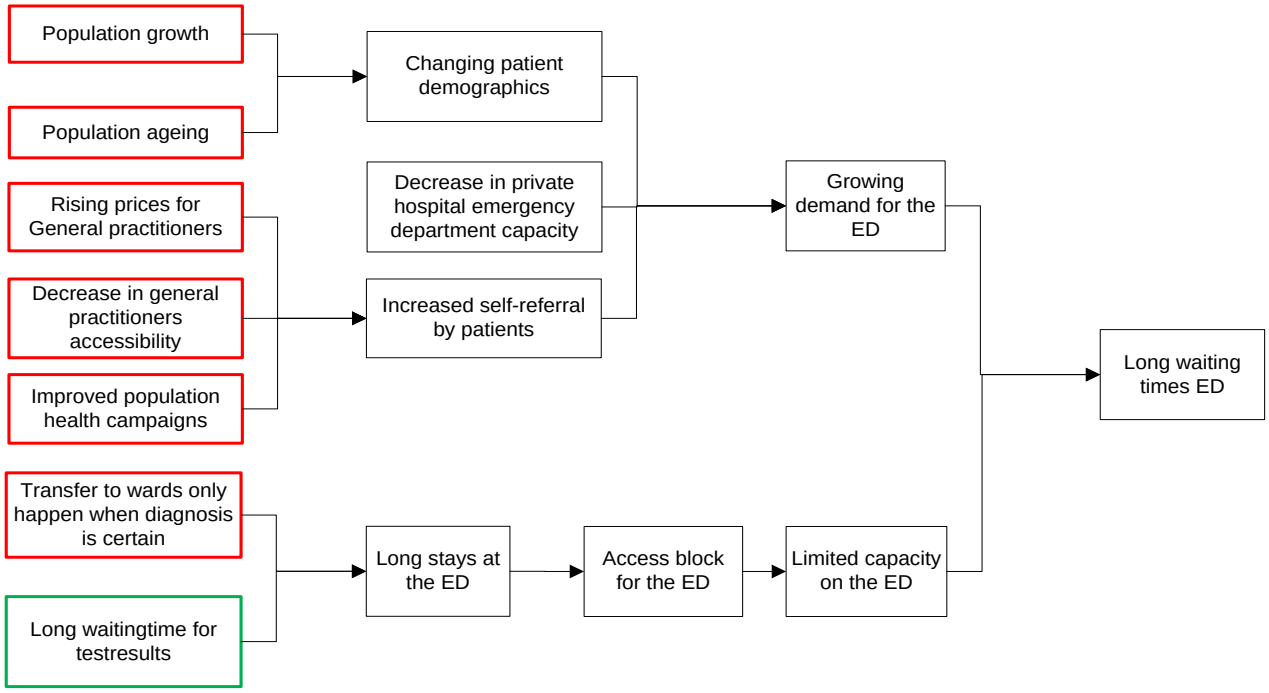


Figure 5: Problem bundle

In this research we want to determine what prevents tests performed by the pathology department of Campbelltown hospital to be finished within 30 minutes. We want to find potential bottlenecks and other reasons for the disrupted flow of pathology samples.

1.3 Research goals and questions

This study is a preliminary study of a large research project performed by the University of Western Sydney in cooperation with Campbelltown hospital. The aim of this research project is to reduce access block in EDs by improving the speed of pathology services using lean system thinking. With this research project UWS wants to address the lack of comparative, independent or critical research and shortage of the published reports that cite evidence for the success of lean system thinking in health care. We aim to get an overview of the current process of pathology tests. This process starts from the moment a request for one or more pathology tests is submitted by a doctor from the Emergency department and stops at the moment the results are returned to the doctor.

The goal of this preliminary research project is to:

Give an insight in the process of pathology testing, the interaction between the ED and Pathology and avoidable activities and make suggestions for possible interventions

To achieve this goal a number of research questions have to be answered:

Q1. How is the process of pathology testing organized?

Section 2.1 and 2.2 describe the current situation, through information gathered by observations and interviews. The process is described by an EPC diagram from gathering the test sample until receiving back the results at the ED. In 2.2 a framework for hospital planning and control delineate the different management areas with their hierarchical decomposition.

Q2. Which stakeholders are involved in the process of pathology tests and what interests and powers do these stakeholders have? How can performance be quantified into KPIs?

Section 2.3 contains a stakeholder analysis which describes all the groups that affect or are affected by the process of pathology testing. A stakeholder analysis is important because this reveals the different (generally conflicting) interests, influence and importance of the parties involved. The interests define what is important for the stakeholders and how each of those stakeholders defines performance. To measure the performance of the current system and the success of possible interventions we need to quantify performance. Key performance indicators (KPIs) are a way to do this.

Q3. Which parts of the process of pathology tests create waste, variability or complexity and thereby cause waiting times of patients on the ED?

In section 3.1, the chandelier model is explained. This model is used to find avoidable activities together with the 8 types of waste from the theory of lean system thinking. . Lean is a logistic paradigm that is leading in the research project performed by the UWS. In section 3.2 avoidable activities in the process are described, by (partly) breaking up these activities the flow of tests can be increased.

Q4. What interventions may reduce the waiting times for test results?

In section 3.3, we give suggestions for interventions that may reduce waiting times for test results in the process of pathology testing.

Chapter 4 outlines conclusions and presents the most promising solutions as recommendations to solve the problem of long waiting times for test results.

1.4 Methodology

To find ways to improve the speed of pathology service, the large multi-disciplinary research project performed by the UWS will use lean system thinking. Lean is a logistical paradigm, which is characterized as reducing waste and adding customer value through re-configuring organizational processes (Womack & Jones, 2003). Lean is mostly derived from the Toyota production system (TPS), which is the way of producing at Toyota after world war II. Instead of mass production like other car manufacturers, Toyota's making profits was based on relentlessly eliminating waste to reduce costs, improve quality and productivity. Waste, which is called *muda* by Toyota, is any activity that absorbs resources but does not create value. There are 8 types of waste: overproduction, over processing, inventory, waiting, transportation, latent talent, motion, defects/rework. In addition to the elimination of waste TPS also aims to improve the production flow, by eliminating unevenness, which is called *mura*. TPS also recommend to minimize *muri*, which is managerial demand of unreasonable work for people and machines.

Lean consists of many techniques and tools to find and eliminate *muda*, *mura* and muri, like value stream mapping, Kanban and five S. The thought process for guiding the implementation of lean techniques is called lean thinking (Womack & Jones, 1996). This process was meant for managers in any company who wished to make their production organization more lean. Lean thinking consists of five steps that were derived from research at 50 companies all around the world that had implemented lean. These five steps are (Womack & Jones, 1996):

- Define value precisely from the perspective of the end customer in terms of a specific product with specific capabilities offered at a specific price and time.
- Identify the entire value stream for each product or product family and eliminate waste.
- Make the remaining value creating steps flow.
- Design and provide what the customer wants only when the customer wants it.
- Pursue perfection

The combination of the thought process and all lean techniques is called lean system thinking (Womack & Jones, 2003).

Lean system thinking has been introduced into healthcare and laboratory operations over the past several years with significant results. A research study by Hassell et al. (2010) shows that after implementing lean process modifications at an anatomic pathology department, the turnaround times of tests were reduced by 4% and the productivity was increased by 8.5%. However, while lean process innovation has been associated with increased health service quality, reduced lead times, and reduced costs, few published reports are comparative, independent or critical, and the available published reports fail to cite evidence. Recent work explicates the need for multi-level investigation of lean health projects that span organizational boundaries. The large multi-disciplinary research project, of which this is the preliminary research, wants to address these theoretical gaps and important societal issues pertaining to emergency health care access.

In this preliminary research, lean system thinking is used to find the most important causes of waste. These findings and suggested interventions can be used in the large research project to cite evidence for the effectiveness of lean in healthcare.

To find sources of waste, a combination of interviews, observations, a rapid improvement event, literature and previous reports from the UWS are used. To get a complete and multilateral view on the process, various groups of stakeholders gave input to the project. The use of different human sources is also expected to contribute to the acceptance of interventions.

Interviews

In order to get a better understanding of the processes and possible trouble spots, we conducted semi-structured interviews. Three interviews occurred with the head of the pathology department, a lab technician and an ED doctor. In addition to these interviews, we have had many conversations with staff from the pathology department and ED.

Observations

To be able to map the process and capture all that happens at the pathology department, we observed lab technicians and collectors. To understand the effect of the test results on the access block on the ED, we also made observations at the ED. A limitation of observations is that the behavior of the ones observed was influenced by our presence. However this is the best way to really capture and understand how the process and the people in this process work.

Rapid improvement event

In addition to training staff in understanding and using lean process improvement tools it is an event to find sources of waste. During these days the staff was explained what lean system thinking is and what tools can be used to find and neutralize sources of waste. An event like this contributes to the acceptance of change by the staff because the changes are initiated by themselves.

1.5 Limitations of the research

Due to a time-limit and other reasons this research has some limitations. As described in the methodology section the information gathering was done by interviews, observations, and a rapid improvement event. These methods give qualitative information about the process of pathology testing. A limitation of this research is the lack of quantitative data. During the research the application for ethics approval, which is needed in every research in healthcare in Australia, was still under consideration by the authorities. It was not possible to get any data from the information system before we had the ethics approval. It only gradually became clear that this approval would not get in before the end of this research.

Another limitation is the absence of (quantitative) analysis of interventions. Without quantitative data it is not possible to draw conclusions about the effectiveness of interventions. When data becomes available the key performance indicators described in section 2.3 can be used to quantify performance. This can be done before and after an intervention and determine the benefit of various interventions.

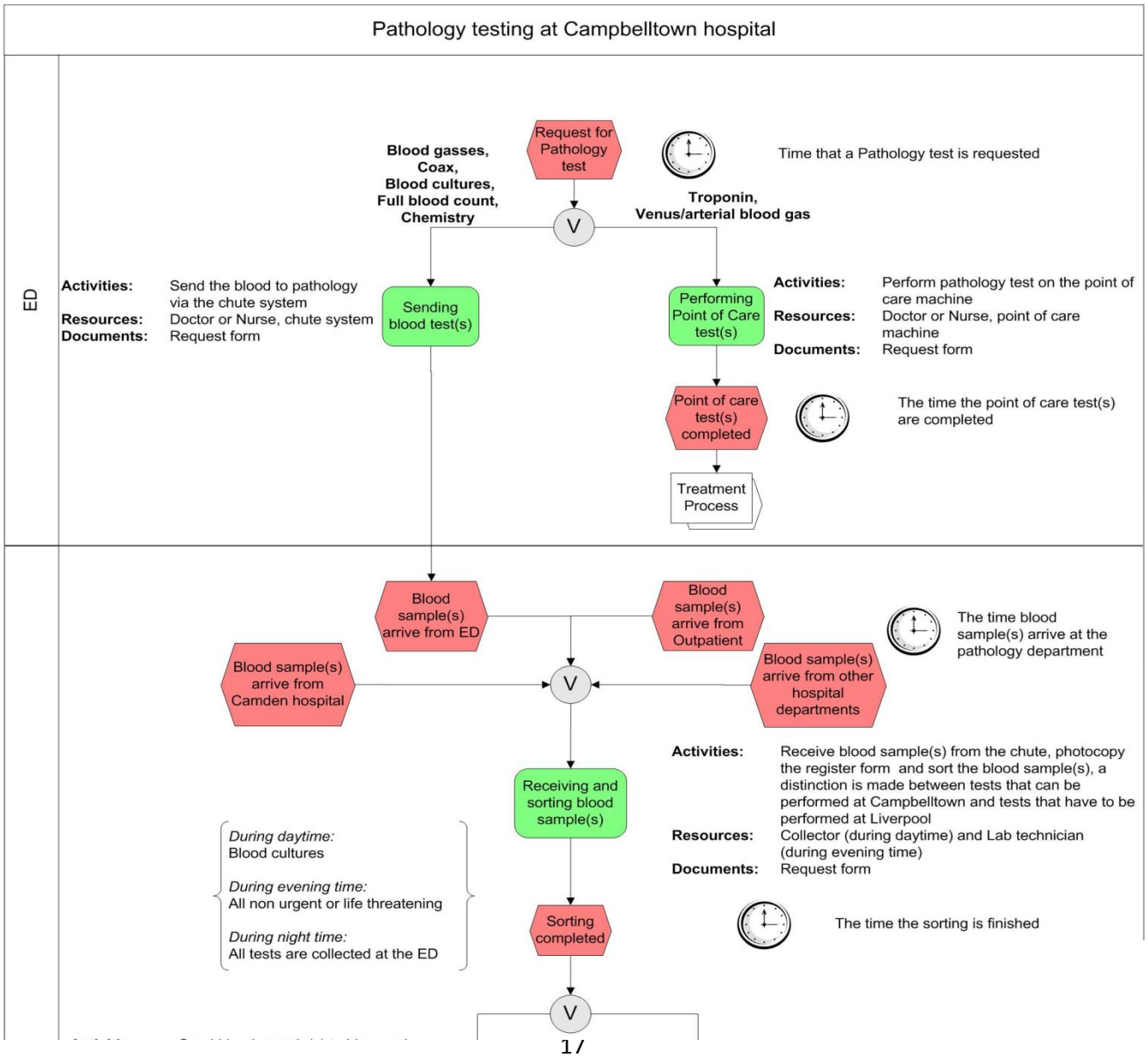
The observations were done in a period of 8 weeks, this period was considered normal in terms of workload and other factors by the staff of both ED and the pathology department. The conclusions and recommendations done apply to such a normal period and could be different in special cases, for example machine break down of a extreme demand due to an epidemic or so.

Chapter 2 Context

This chapter discusses the context of the situation. Section 2.1 gives an overview of the system layout and operating procedures. Section 2.2 presents a generic framework for hospital planning and control, which is used to analyze the process of pathology tests in Campbelltown hospital. Section 2.3 contains a stakeholder analysis and gives an overview of the key performance indicators that can be used to measure performance of the process.

2.1 System layout

To find sources of waste, variability, and complexity an in-depth understanding of the system is needed. The process where this research focuses on, starts from the moment a pathology test is requested and ends with the collecting of verified results. Figure 6 shows the flow of pathology tests using an Event-driven Process Chain (EPC). This section contains a specification of the content of the EPC.



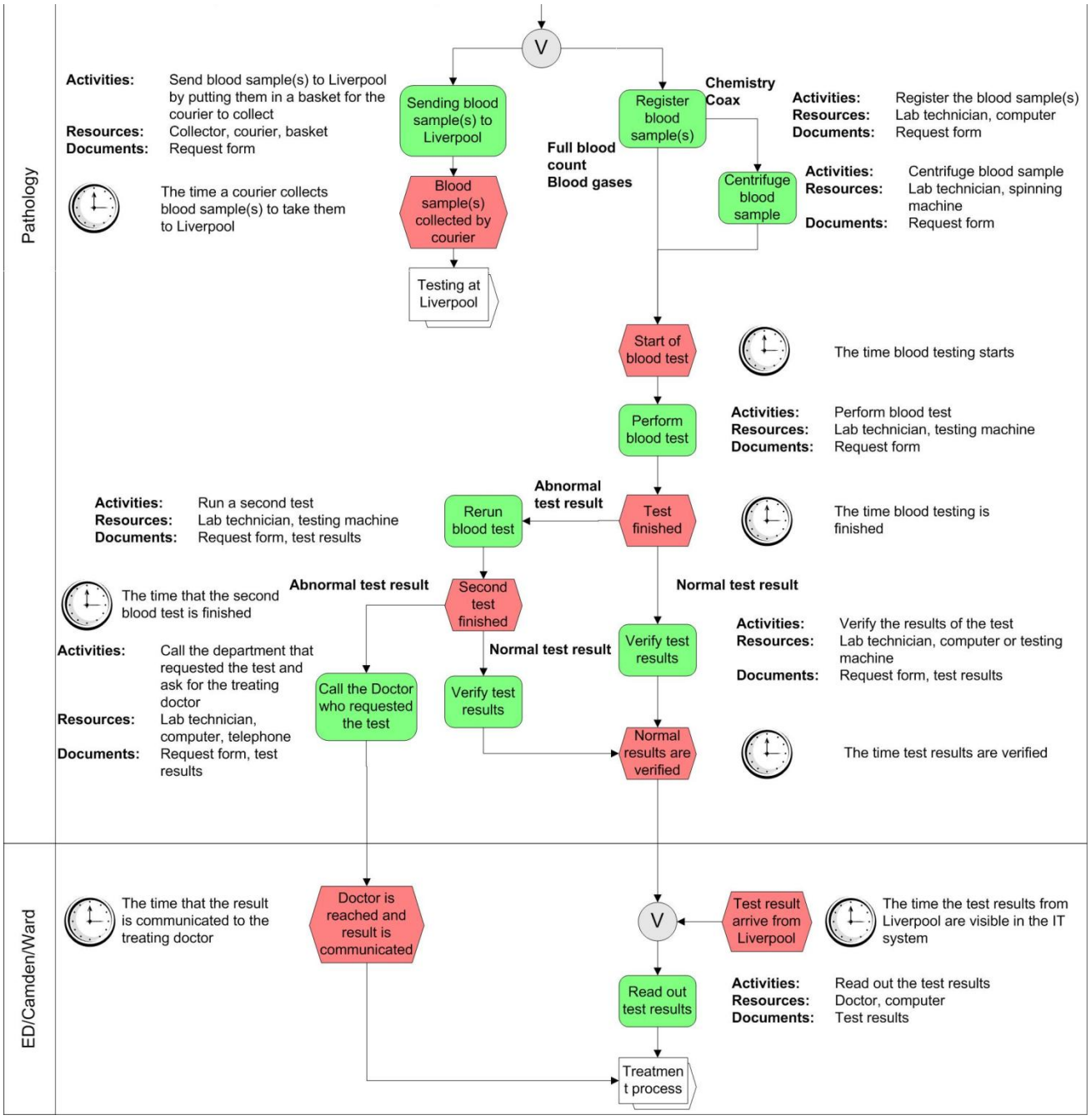

Pathology
V
Activities: Send blood sample(s) to Liverpool by putting them in a basket for the courier to collect
Resources: Collector, courier, basket
Documents: Request form
Sending blood sample(s) to Liverpool
Blood sample(s) collected by courier
Testing at Liverpool
The time a courier collects blood sample(s) to take them to Liverpool
Register blood sample(s)
Chemistry Coax
Activities: Register the blood sample(s)
Resources: Lab technician, computer
Documents: Request form
Full blood count
Blood gases
Centrifuge blood sample
Activities: Centrifuge blood sample
Resources: Lab technician, spinning machine
Documents: Request form
Start of blood test
The time blood testing starts
Perform blood test
Activities: Perform blood test
Resources: Lab technician, testing machine
Documents: Request form
Abnormal test result
Test finished
The time blood testing is finished
Rerun blood test
Activities: Run a second test
Resources: Lab technician, testing machine
Documents: Request form, test results
Abnormal test result
Second test finished
The time that the second blood test is finished
Normal test result
Verify test results
Activities: Verify the results of the test
Resources: Lab technician, computer or testing machine
Documents: Request form, test results
Normal test result
Verify test results
Activities: Call the department that requested the test and ask for the treating doctor
Resources: Lab technician, computer, telephone
Documents: Request form, test results
Call the Doctor who requested the test
Normal results are verified
The time test results are verified
ED/Camden/Ward
The time that the result is communicated to the treating doctor
Doctor is reached and result is communicated
V
Test result arrive from Liverpool
The time the test results from Liverpool are visible in the IT system
Read out test results
Activities: Read out the test results
Resources: Doctor, computer
Documents: Test results
Treatmen t process
Event
Function
OR Connector
Process Path
Time Stamp

Figure 6: EPC

Request for pathology tests

The process starts with an incoming request for one or more pathology tests. These tests can be requested with the IT system of the hospital. The hospital uses Citrix software and each department has access to applications suitable for their IT needs. For the pathology department at Campbelltown hospital tests can come from the Emergency Department but also from other hospital departments, Camden hospital and patients outside the hospital. The category of tests that come from outside the hospital are called outpatient samples and are samples that for example need to be tested on glucose tolerance for pregnant woman or the amount of red cell anti bodies in blood.

Samples from the ED or other hospital departments arrive at pathology via the chute system. This chute system is an air-pressure system that can send small things packed in a socket to other hospital departments. A sample that is coming from the ED is put into a socket together with its printed request form and the chute system delivers the sample to pathology, which is one level up, in about 1 minute.

Not all tests from the ED are sent to pathology, because for some tests this will take too long in a life threatening situation. For this reason there are two point of care (PoC) machines on the ED that can perform some specific tests. One machine is able to do a venous/arterial blood gas test and the other machine can perform a troponin test which is vital in case of a heart attack. These machines are maintained by staff from pathology every day.

Receiving and sorting samples

Samples arriving at the pathology department are coming from multiple sources. The samples from the ED and other hospital departments that cannot be tested at the PoC arrive via the chute system or are brought into the lab at the end of the ward rounds, which are held twice a day. The samples coming from Camden hospital are brought in by a courier. Samples of outpatients are taken from them at the pathology department or are handed in at the reception desk of the pathology department.

Not all tests can be performed by the pathology department at Campbelltown, partly because pathology does not have the right equipment and partly due to the fact that the pathology department does not have a 24/7 service. Tests that can be carried out at Campbelltown are put on a counter so lab technicians can take them into the lab. All other tests are put into a basket that is collected by a courier on set times during the day to bring them to Liverpool hospital.

The types of tests that are sent to Liverpool change during the day. A day of 24 hours can be split into roughly three parts, namely normal hours, after hours and night-time hours. Table 1 gives an overview of the different parts of the day and the location where the samples are tested.

	Normal hours (07:00-16:00)	**After hours (16:00-00:00)**	**Night-time hours (00:00-07:00)**
Campbelltown pathology department	Only test that cannot be performed are sent to Liverpool	Only test that cannot be performed are sent to Liverpool	All tests are sent to Liverpool
Camden hospital	All tests are sent to Campbelltown	All tests are sent to Liverpool	All tests are sent to Liverpool

Table 1: Test locations

Blood testing

A lab technician takes the blood samples from the counter and registers a batch of samples at the computer into the application for pathology called CCIS AppBar. The lab technician checks if the name on the label matches with the name on the request form. After all of the samples in the batch are registered the lab technician takes the blood samples to the different machines. The samples that need to go in to the Chemistry machine and the COAX first have to be centrifuged in the spinning machine; this separates the blood into different layers of liquid. Appendix 1 shows a floor plan of the pathology department and appendix 2 gives an overview of all available machines.

Verifying results

The results of the blood tests need to be verified by a lab technician. All normal results are verified and the person who requested the test is able to see the result in the accessible application of the IT system, for ED this is CCIS Powerchart. If an abnormal result shows up the lab technician has to ensure that it was not an error from the machine, so the test is rerun. An abnormal result means that one of the tests values is unexpectedly low or high. In this judgment all sort of factors count, like for example the results of previous tests. If the second test shows a normal result, the (first) abnormal result is attributed to the machine and the result is verified. If the machine returns the same abnormal result in the second test, the lab technician can be sure that result is really abnormal. In this case the lab technician calls the doctor who requested the test to communicate the abnormal result.

If a test is send to Liverpool hospital, there the test pass through the same process steps, it only takes more time in most cases because the sample first has to be transported to Liverpool.

2.2 Planning and Control

In the previous section we argued that planning and control plays an important role in the process. Many decisions are made about time plans, prioritizing, the use of material and machines. In this section various functions are analyzed on their decision level and area of interest.

2.2.1 Hospital framework

To analyze the important functions in the process we use a hierarchical framework for health care planning and control designed by (Houdenhoven, Wullink, Hans, & Kazemier, 2007). It can be used as a tool for managers, clinicians and experts on planning and control to formulate objectives in terms of performance indicators on all organizational levels and in all areas of interest. The horizontal interaction can be used to make a trade-off between different and sometimes conflicting objectives. The vertical interaction within a managerial area serves as a tool to formulate goals and restrictions on lower levels that comply with the hospital's strategic objectives.

The dimensions of the framework are generic but the content can be filled for any hospital case. Figure 7 shows this framework filled out for the process of pathology testing. Section 2.2.2 clarifies the content of the different areas of interest.

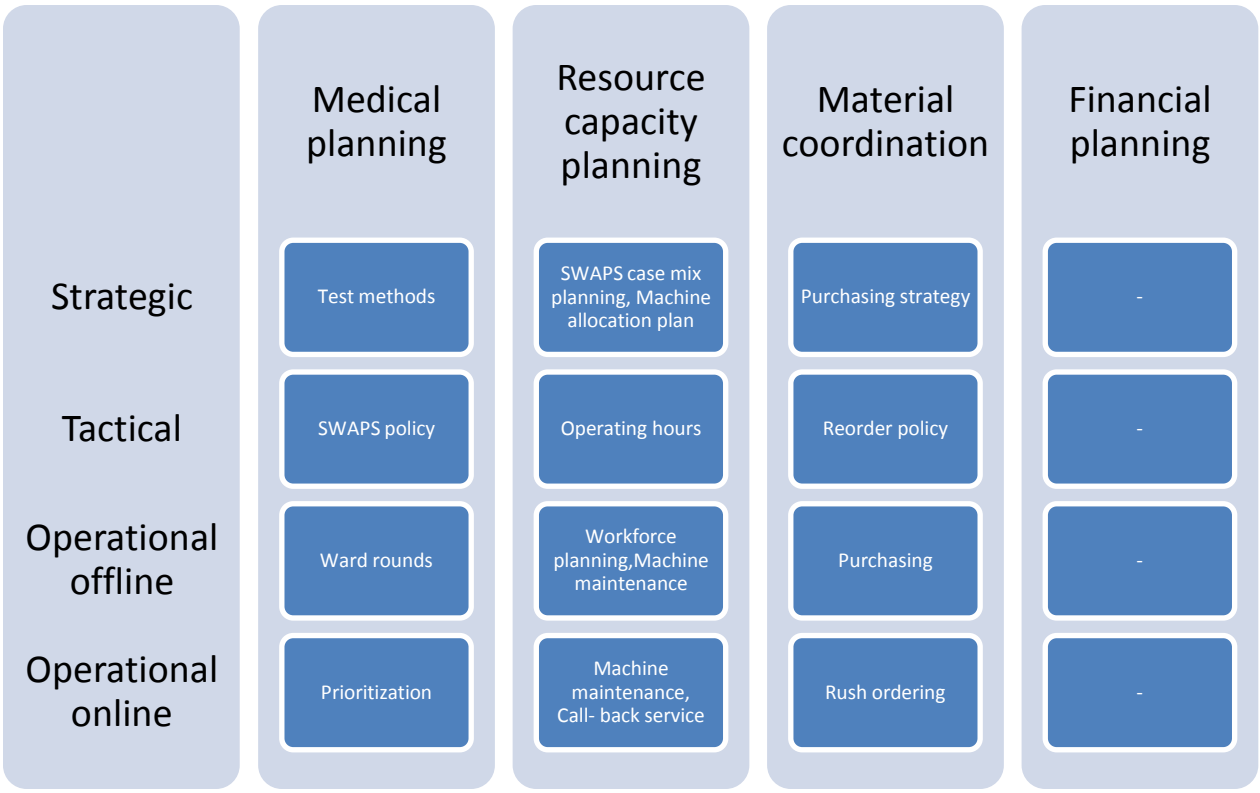


Figure 7: Hospital Planning and Control Framework (Houdenhoven, Wullink, Hans, & Kazemier, 2007)

2.2.2 Areas of interest

Every area of interests starts with a long-term objectives or a policy on strategic level. This is an objective or policy made by the board of a hospital/department or a government institution. This decision is translated into one or more tactical objectives. On the offline operational level, the objectives have to be adopted in actions, like the planning. The operation online level is about decisions or action that have to be made on the work floor and are most of the time ad hoc. A good protocol can help enormously in making the right decision.

Medical planning

The medical planning is all about the planning of medical activities. On the highest level it is decided which test methods are used for the testing of blood and other human fluids. This decision is made on a high level and is used as the basis for the South Western Area Pathology Service (SWAPS) policy manual. This manual is about the prioritization of specimens into three categories: acute life-threatening, urgent and routine. These three levels have an associated time frame in which the results have to be ready after arriving at the pathology department. For acute life-threatening this time frame is one hour, for urgent this is two hours and for specimens in the routine category the time frame is four hours. This prioritization is made by the medical staff member that requests the test and is done online. An offline planning decision is the scheduling of the ward rounds. During these ward rounds collectors from the pathology department visit hospital departments to collect samples from inpatients. After a complete round the samples are brought back to the pathology department to be tested by the lab technicians.

Resource capacity planning

Resource capacity planning is important to efficiently use the hospital's scarce resources. This could be done by enlarging the utilization for example. Another important target is to minimize the overtime of medical staff because overtime is more expensive than regular hours and has a negative impact on the motivation of the personnel. For the pathology department this area of interest starts with the SWAPS case mix planning. In this planning the amount of necessary tests is forecasted. Once the number of tests is indicated a machine allocation plan can be made, because the SWAPS includes 12 institutes a decision has to be made in which institutes a pathology lab is based and which machines have to be in those labs. In this allocation plan also the strategic objectives from the medical planning have an important role. To meet the strategic objectives of maximum test times and the amount of tests the amount of operating hours is defined. Every month the head of the pathology department, who is the most experienced lab technician, makes a roster for all collectors and lab technicians. In the online planning it is all about reacting to unforeseen events. The pathology department has a call service for those cases. During normal and after hours there is always someone in the lab in case of an emergency but during the night no staff is on duty. To be able to respond to emergency cases the pathology department has a call-back service: There is one of the lab technicians on standby, which means that he or she should be in the hospital within half an hour. Another online planning issue is the planning of machine maintenance. The machines that are used by lab technicians are very precise instruments and need to be maintained, checked and calibrated every day. The moments to do this are planned in an offline planning but if there is a peak or a dip in the amount of tests lab technicians can decide to postpone or advance the maintenance for one or more machines.

Material coordination

Material coordination is about the distribution of materials to support the primary process. On strategic level a choice of purchasing strategy is made, this contains decisions about centralized or decentralized procurement, the size and location of inventory. Also goals about the maximum service time and service level have to be set. Once the parameters of maximum service time and service level are set an order policy can be adapted that meets these specifications at the lowest costs. On offline planning level the different products have to be ordered according to their order policy, delivery time and review time.In case of an unexpected run on an item which creates an undesirable situation an online rush order could be placed. These rush orders are most of the time more expensive than normal orders. A reorder policy describes when a new order should be placed and therefore influences the number of rush orders. The reorder policy has to be reviewed every once in a while to make sure that normal demand can be satisfied from normal orders and a possible safety stock for peaks in demand.

Financial planning

Financial planning is outside the scope of this research.

2.3 Stakeholder analysis

A hospital is a very complex organization with many different entities with very diverse interests. In a product manufacturing process for example the (paying) customer is easily located, but in public health services a variety of funding groups exist and co-payments are common. Furthermore, the consumer, in the role of patient, is relatively passive and often excluded from process and purchase decisions (Hayes, Reed, & Fitzgerald, 2010). To understand the system and to be able to give recommendations about the system these different entities with their interests have to be identified. A stakeholder analysis is a tool to identify the entities that are involved in a process. With all stakeholders identified we are able to define performance blood testing process. This performance is quantified in key performance indicators.

2.3.1 Different types of stakeholders

There are many different types of stakeholders as described by (Mitchell, Agle, & Wood, 1997). In their article a distinction is made between 7 types of stakeholders. To facilitate discussion the authors gave every type of stakeholder a descriptive name, as can be seen in figure 8. Stakeholders have a certain priority based on the attributes: urgency, legitimacy and power. The salience class of a stakeholder is determined by the number of attributes of a stakeholder. For example a dominant stakeholder has power and legitimacy but no urgency, so its salience class is 2. Figure 8 shows all types and classes of stakeholders.

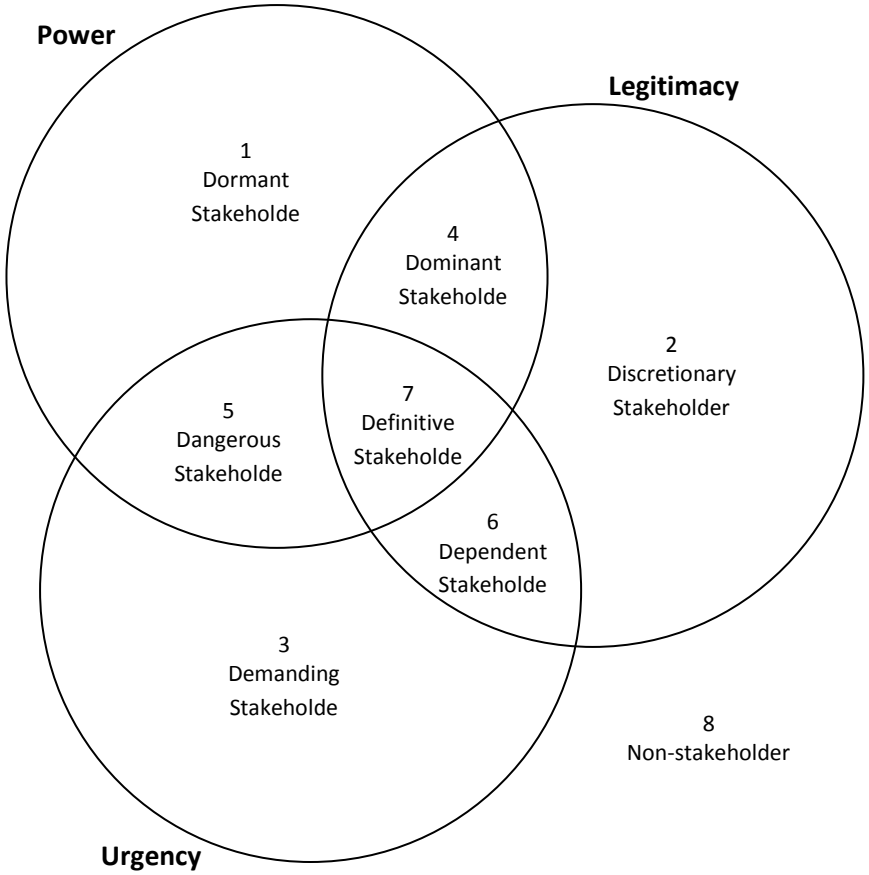


Figure 8: Stakeholder Typology (Mitchell, Agle, & Wood, 1997)

Urgency is related to the degree to which stakeholders can claim immediate attention (timely response) from management. Legitimacy refers to a perception that the actions of an entity are desirable, proper or appropriate, and power refers to relationships between social actors that allow one to influence another to act in a desired way (Hayes, Reed, & Fitzgerald, 2010).

Table 2 shows a list of process stakeholders in the case of the pathology service of Campbelltown hospital.

Stakeholder type	Attributes	Actions	Stakeholder in pathology service
Dormant stakeholder	Possesses power to impose will, but do not have an immediate legitimate relationship or urgent claim	Regulation, standards	State or Commonwealth Government
Discretionary stakeholder	Possesses legitimacy, but has little immediate power or urgency claim	Important for quality and safety	Community representatives and patients
Demanding stakeholder	Possesses urgency claim, but no power or legitimacy	Reinforcing entitlements	Patients
Dominant stakeholder	Possesses power and legitimacy, but has little urgency claim	Required reporting on business outcomes	NSW health, hospital GM, pathology department manager
Dependent stakeholder	Possesses urgent and legitimate claims, but has no power	Depends on other stakeholders who have common interests	Lab technicians and collectors, patients
Dangerous stakeholder	Possesses urgency and power, but not legitimately	Coercion to influence relationships	
Definitive stakeholder	Possesses urgency claim, legitimate relationship and the power to impose will	Most important stakeholder to satisfy	All areas the pathology department services, e.g. ED doctors, other hospital departments, Camden hospital and (out)patients

Table 2: Stakeholder Analysis of pathology service (Hayes, Reed, & Fitzgerald, 2010)

2.3.2 Stakeholder interests and Key Performance Indicators

Some stakeholders have conflicting interests, for example the fact that ED wants their results as fast as possible, but the lab technicians and collectors do not want to rush all day. A solution would be to hire more personnel or buy faster machines but this is not always possible because the hospital only has a certain budget that is controlled by the general manager. Table 3 shows a list of the stakeholders and their interests related to the process of pathology testing and its effect on the ED.

Stakeholder	Interest(s)
(out)Patients, Community representatives	Minimize waiting time at pathology (outpatients) Minimize waiting time for ED admission
Lab staff, Pathology department manager	Maximize work satisfaction, including minimize work pressure
ED doctors	Minimize the number of resent tests Minimize waiting time for test results
hospital departments, Camden hospital	Minimize waiting time for test results
Hospital GM	Minimize overrun of the budget Maximize positive perception about the hospital
State or Commonwealth Government, NSW health	Minimize waiting time for ED admission

Table 3: Stakeholder interests and KPIs

With those interest we are able to determine performance from every stakeholder perspective. To benchmark the current performance with other hospitals or with the own performance in the future/history and to determine the benefit of different interventions we need to quantify performance. Quantify performance is possible with key performance indicators (KPIs). We formulate KPIs that cover the interests of all stakeholders.

Waiting time

It is clear from the interests of the stakeholders and the problem description that minimization of the waiting time for test results is desired. There are multiple waiting times that have to be measured, like the waiting time of patients but also the waiting time of doctors and other hospital staff that depend on test results. The KPIs that should indicate the performance on waiting time are described below.

- **Average emergency room patient waiting time**
  The average time a patient has to wait between registration and admission to the ED. This could be measured for each triage category. *Take the average time between the time stamp of registration and the time stamp of admission, if preferred this could be done per triage category.*

- **Average outpatient waiting time**
  The average time a patient has to wait between registration and the moment a pathology collector calls the patient in to take the test(s). *Take the average time between the time stamp of registration and the time stamp of the collection from the waiting room.*

- **Percentage of the tests that is completed within the given time frame**
  Each test got a given time frame that indicates the maximum time until the results have to be ready. This time frame depends on the priority that is given to the test. *Calculate the time between the time stamps of registration at the pathology department and the time of verification of the test results. Divide the number of tests that were completed within the given time frame by the total number of tests and multiply with 100%.*

Quality

Quality in blood testing can have vital influence, because doctors' decisions are based on the test results. There is one KPI that measure the performance in terms of quality.

- **Percentage of pathology test results errors (1,2)**
  A test result error could occur in two ways, on the one hand it could be the case that the result is not correct, on the other hand it is possible that the result does not contain the desired data. The first possibility is very important because such an error could lead to a wrong treatment, with all its consequences. *(1)The number of test that were not correct divided by the total number of tests, multiplied with 100%.*
  The possibility that the result does not contain the desired data is important for the quality of care as well as for the waiting time. If this is the case, the pathology department has to be called and the right test has to be requested. *(2) The number of results that did not contain the desired data divide by the total number of tests, multiplied by 100%.*

Costs

To measures the performance of the pathology testing process there is one KPI in terms of costs.

- **Average cost per pathology test**
  There are three locations where blood can be tested, namely the point of care machines, the pathology department in Campbelltown and the pathology department in Liverpool. The costs of those three parts that are dedicated to Campbelltown should be included in this calculation. *Add up the costs for pathology testing on the point of care machines, the costs for running the pathology department in Campbelltown and the costs that Liverpool charges for testing samples from Campbelltown. Because the pathology department also tests samples from Camden the total costs should be decreased by the costs that Campbelltown charges to Camden hospital. The total remaining costs should be divided by the total amount of tests requested in Campbelltown hospital.*

Employee satisfaction

The satisfaction of employees can be measured by two KPIs.

- **Average score on employee satisfaction surveys**
  To measure the employee satisfaction a periodically survey could be used. This survey could map the satisfaction on different elements of the job. *Make a survey that touches upon the important elements of the job and conduct this survey periodically, take the average of the scores of all employees in one period.*

- **Percentage of time devoted to primary activities**
  Lab technicians are well trained/educated employees that are specialized in the testing of human specimens. A big part of the satisfaction of employees is about the time spent on the activities they are trained for. The same holds for collectors. *Map the time spent by lab technicians/collectors on different activities. Make a distinction between the activities on the scale described in chapter 3. Divide the time spent on primary activities by the total time spent.*

Chapter 3 Activity analysis

The first step of the lean thinking process as described in section 1.4 is to define value from the perspective of the end customer. In Chapter 2 we defined multiple end customers of the process of blood testing and defined the KPIs to measure performance, which implies value for the end customer. Followed by the identification of the value stream, which we did via the EPC. The next step is to eliminate waste. In this chapter waste is found in the form of avoidable activities. Section 3.1 describes the model that is used to find avoidable activities in the process of pathology testing. Section 3.2. gives an overview of the application of the chandelier model that resulted in the causes for avoidable activities. Section 3.3 provides interventions that may influence the causes of avoidable activities so that the time that is spend on those activities can be reduced.

3.1 The chandelier model

To find ways to improve the speed of pathology service, we analyze activities performed by the staff. A distinction between the activities is made into five categories, based on their relation to the primary process. The first category consists of the activities of the primary process, which is testing. The other activities are divided over the other 4 categories, where quintary activities have the least connection with the core business of the staff. Table 4 shows the different categories and their connection to the core business (Sambeek, 2005).

Primary activities	Everything that has to be done during a test
Secondary activities	Everything that has to be done before or after a test
Tertiary activities	Everything that is directly necessary for testing, but not for every single test
Quartary activities	Everything that is not directly necessary for testing, but does create value for the patient
Quintary activities	Everything that does not create any value for the patient

Table 4: Overview of activity categories

Tertiary activities are activities that have to be done once a day or once a week. Directly necessary for testing means that testing cannot take place before the specific activity is finished.

To see if an activity can be avoided, we use the types of waste as described by Womack & Jones (1996):

- Overproduction
- Over processing
- Inventory
- Waiting
- Transportation
- Latent talent
- Motion
- Defects/rework

If an activity contains one of these forms of waste it could be an activity that has the potential to be (partly) avoided. All the activities that are potentially (partly) avoidable, are tested on their relevance.

Does changing or removing this activity has a positive impact for the organization? in other words does the activity has a high frequency of occurring and/or a great impact on the process.

Not all activities that are relevant and have the potential to be (partly) avoided, can be avoided. This is because for some activities it is simply not possible to avoid them. To check whether it is realistic to avoid an activity it should satisfy the following criteria:

- Avoiding the activity should be realistic
- The quality of health should be preserved
- The quality of labor should be preserved

The steps of potential, relevance and feasibility result in a list of activities that are interesting to be (partly) avoided. From the fact that an activity is avoidable we can conclude that this activity occurs too much. The next step aims to find the cause(s) of the frequent activity occurrence. These causes can have different relevance and can be influenced to a different degree. It is also possible that one cause is responsible for multiple activities occurring too often. This makes the cause only more attractive to deal with.

Figure 9 shows the model with the steps described above. The top half of the figure is funnel-shaped, to illustrate the decreasing number of activities as more steps are passed through. The shape of the entire figure is like a chandelier, this is why this is called the chandelier model.

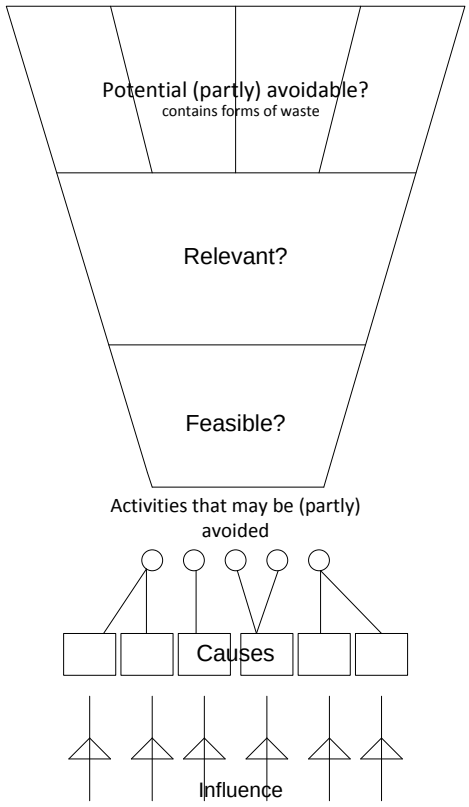


Figure 9: The chandelier model (Sambeek, 2005)

3.2 Applying the chandelier model

In this section we show the results of the use of the chandelier model. From all the activities performed by the staff the potential avoidable ones were selected. These activities were tested on their relevance and the feasibility of really breaking up (a part of) the activity. Table 5 shows the remaining activities resulting from the chandelier model.

Avoidable activity	Type of waste
Wait for tests to come in	Waiting
Collect and sort blood samples	Motion/ inventory
Send blood sample(s) to Liverpool	Transportation
Register blood sample(s)	Motion/inventory
Re-perform blood test	Rework
Call the doctor who requested the test	Waiting/ motion
Answer calls from doctor about requested test	Over processing

Table 5: Avoidable activities

The causes of these avoidable activities were found by observations and interviews or conversations with persons involved in the activities. Sections 3.2.1 until 3.2.3 describe these causes.

3.2.1 Communication

The IT system

One of the IT systems that is used in Campbelltown hospital is CCIS Powerchart, this system facilitates ordering blood tests. Labels and a receipt are printed and once the labels are attached to the blood tubes, the specimens and the receipt are sent to the pathology department. In the past this was all done by hand and with the use of written receipts. After the implementation of Powerchart it is still possible to make a hand written receipt. The problem with the hand written receipts is that it takes much time for staff of the pathology department to enter the written request into the system, which is needed for communicating the test results.

It also happens that the printed labels are attached to the tubes in a wrong way. The text on the labels should be in a specific position to be read by the machines at the pathology department. If the label is attached in a wrong way the registration of blood samples takes extra time.

The priority system

One of the options in Powerchart is to indicate a level of priority for a test. There are 3 levels of priority, each of these levels has a maximum time which starts after arrival at the pathology department until the results have to be ready. The priority levels and their time frames are listed in table 6 (SWAPS, 2010).

Priority level	Time frame
Acute Life-Threatening	Within 1 hour after receipt in laboratory
Urgent	Within 2 hours after receipt in laboratory
Routine	Within 4 hours after receipt in laboratory

Table 6: Priority levels of blood samples (SWAPS, 2010)

The problem with the priority system is two sided: on the one hand do all ED doctors indicate their requested test as Acute Life-Threatening, even if this is not the case. The ED doctors just want their results as fast as possible and therefore indicate all their tests with the highest priority. On the other hand there is not much attention for the priority level in the pathology department. The lab technicians at the pathology department test specimens according to a first come first serve principle. The only indication of priority is a computer screen that indicates if there is a test that is exceeding its time frame according to the priority of the test. The staff of the pathology department can see a red line on the screen and have to search where this specimen is and then perform this test as fast as possible.

The classification system

To simplify the sorting process the tops of the tubes, containing the test sample, were given colors. Each color corresponds to a machine on which the requested test can be performed. During interviews with staff from the pathology department it was indicated that it happened a lot that the color of the top did not correspond to tests requested. This results in the performing of wrong test and as a consequence in rework or extra acts by lab technicians. In the worst case a tube that could have been tested in Campbelltown is sent to Liverpool, which takes over half an hour.

Telephone communication

There is a lot of telephone communication between the Emergency Department and staff from Pathology. A proportion of this communication is inevitable because an abnormal test result has to be communicated with the treating doctor. In these cases it takes in general more than one phone call to reach the doctor, which is frustrating and time consuming for the lab technicians.

In addition to these inevitable phone calls there is also a lot of time spent on phone calls that could be saved. Phone calls are made by the pathology department about unreadable handwriting and vagueness about requested tests. But also the ED doctors frequently use the phone to ask about the time the test results will be ready and request an extra test on a specimen that is already sent.

3.2.2 Logistics

Allocation of samples

There are secondary activities like the transportation of samples. In the case of pathology testing, the transportation consists of getting the specimens to a machine that is able to perform the tests needed. The results of the tests are in most cases automatically added to the digital patients' record in the hospitals information system.

For the Emergency department of Campbelltown hospital there are three options to get their specimens tested.

- The fastest option with the least amount of transportation is using a point of care machine. Drawbacks of the point of care machines are the fact that only a small number of tests can be performed on those machines and the high costs of a test on one of these machines, especially because only the emergency department can make use of those machines.

- Via the chute system, the specimens can be delivered at the pathology department without much effort and transportation time. Doing tests in the lab takes longer because there are multiple departments that are supported by the pathology department.
- The last option is that tests are picked up by a courier and brought to Liverpool hospital to get tested at the large pathology department over there. In table 7 an overview is given of the three different options and their characteristics transportation time, costs per test, amount of tests available and availability during the day.

	Transportation time	Costs per test	Amount of tests available	Availability during the day
Point of care machine on ED	negligible	Very high	Only tests for life threatening situations	24 hours per day except for maintenance (23 hours per day)
Campbelltown pathology department	Several minutes	Low	Most used tests (70 percent of the total amount of tests)	Between 8 in the morning and midnight (16 hours per day)
Liverpool Pathology department	Over half an hour	Very low	All possible tests as set by the SWAPS	24 hours per day

Table 7: Different pathology options

From table 7 it is clear that there is not one best solution to pick, it is always an assessment between costs on the one hand and time on the other.

Some tests are performed at the point of care machines at the ED while there is no time pressure. Sending these samples to the pathology department would save money. At the same time it might be cost effective to send other samples from Campbelltown to Liverpool. This could free capacity for the more urgent tests at pathology.

3.2.3 Planning

Ward rounds

As described in paragraph 2.1, collectors from the pathology department make two ward rounds per day. During these ward rounds specimens are collected from all hospital departments except the ones that send their samples via the chute system. The first round is from 05:30 until 10:00 and the second round starts at 13:00 and brings in the specimens at 14:30.

When the collectors return to the pathology department they bring with them a large number of tests. This results in a lot of work at once, in other words two huge peaks in demand for testing are created. Before these samples come in, it happens that the lab staff has been idle for a while. The type of waste is waiting and is a consequence of the unevenness in demand. *Muda*(waste) and *mura*(unevenness) are closely related.

Outpatients

Outpatients are patients that are coming into the pathology department to get their blood taken or handing in a specimen to be tested. Outpatients can enter the pathology department without appointment on weekdays between 8:00 and 16:00. Because there are no appointments it is possible

that there is a large difference in demand for tests regarding outpatients. This is difficult to take into account while making the planning.

3.3 Interventions

We want to influence the causes of avoidable activities so that the time that is spend on those activities can be reduced. The interventions that are suggested in this section are expected to have a positive impact on these causes. The causes that we try to take on are the once that, just like in paragraph 1.2, are relevant and can be influenced.

3.3.1 planning

A better planning can reduce at least one of the avoidable activities, namely *wait for tests to come in*. Also the workload can be equalized over the day by which there are less stressful situations. This will result in a reduction in turnaround time of tests and a higher employee satisfaction.

In paragraph 2.2 the hospital planning and control framework was discussed. Planning and control is organized at different decision levels, from strategic until online operational level. In this research we discussed problems of multiple decision levels, of which the ones on operational level are in general a lot easier to change in comparison to the decisions on strategic and tactical planning. Although the problems at operational level are easier to solve or improve, the effect of these changes will be a lot less significant than changes on strategic and tactical level.

Reduction of variability

In the process of pathology testing the demand is coming from a lot of sources like the ED, other hospital departments and Camden hospital (see paragraph 2.1). All these different sources have their own distribution of demand over time and sorts of tests. These differences in demand are a large source of variability. A very important way to reduce sources of variability in demand or deal with variability in an efficient way is via planning. By planning, the number of tests over time can be more equal spread and in cases where this is not possible, the planning of resources can be optimized to reduce the influence of variability.

There are some sources of demand that cannot be influenced, like the requests for tests coming from ED. But the time of return of the ward rounds and the number of ward rounds could be influenced because it is at the operational planning level and these ward rounds are performed by collectors from pathology. The planning of ward rounds should be attuned with the demand that cannot be influenced. On the moments that the demand from uncontrollable sources is low, it would be perfect to have collectors come back from a ward round with specimens to test. Another possible intervention can be the planning of outpatients arrivals at the pathology department. With this planning it is possible to fill up dips in demand from uncontrollable sources or we are able to plan staff availability more in line with demand from outpatients.

Proper use of priority system

On the operational planning level there is another possibility to improve. The priority system in the current form does not add much value because it is used inappropriately. There is a large difference between the tests coming into the pathology department. Some of those tests do not have any urgency

while for others time could be of vital importance. The tests with a vital urgency should be tested as soon as possible. This means that doctors and nurses should indicate their tests in accordance with their priority level and pathology staff should use this prioritization instead of a first come, first serve policy. To make this happen doctors and nurses should be explained what the priority level imply and the pathology staff should get instructions how to use the priority system in their daily job. It could be necessary to make the priority level more visible, for example by giving the labels on the tubes different colors or a more prominent visual indication in the IT system when tubes are registered.

Research possibilities for operating hours and machine allocation

Operating hours and machine allocation are two areas where the manager of the pathology department does not have the power to take decisions on his own. The reasons why these decisions cannot be made by the pathology department manager alone are the cost implications of such decisions and the effect on other hospital departments. These decisions are made at the strategic and tactical planning level, as described in paragraph 2.2. A research on the best configuration for those areas could be interesting because of their large impact on the cost per test and the turnaround time of a test. A different machine allocation or other operating hours could reduce the transportation time and cost. For tests that do not have a tide time frame economy of scale could be achieved. So another allocation of test could save time as well as money.

3.3.2 Communication

Through optimization of the communication it is possible to perform the activities from table 5 in a more efficient way, so they will take less time. Optimization of communication will be beneficial for both communication coming into the pathology department as well as communication going out of the pathology department.

Training of ED staff

Activities like registration of blood samples and re-performing tests take needless time from pathology staff. The reason that those activities take more time than necessary is because the way of supply is not optimal. Requests are still possible in written form, the wrong tops for tubes are used and labels are wrongly attached. Also the prioritization as mentioned above is not optimal. The ED staff should be explained and get demonstrated which options are not optimal and how the existing tools can be used to optimally supply pathology. Show ED doctors around at the pathology could also give them a better idea what happens to their samples while waiting for their results.

Better use of communication tools ED

In table 5 there are two activities concerning telephone communication between the pathology department and the ED. In general it takes more than one phone call from a lab technician to reach the ED doctor to tell him about an abnormal test result. It would save a lot of time if the doctor could be reached at once, for example via a mobile phone or buzzer.

Results from finished tests are entered into the IT system without any notification. This costs a lot of time for ED doctors to check whether or not their results are in already. It is also possible without notification that the test result is already in for a long time before the ED doctor sees it. If it would be

possible to let an ED doctor know when a result is ready this would save a lot of time. A message could be sent to a mobile phone, buzzer or a pop-up in the IT system.

Alignment of goals

During the interviews it became clear that the expectations from the ED and the goals of pathology are not the same. The expectations about the turnaround time for test differs between ED and pathology. Also expectations about the percentage of tests that should be within the maximal time frame are much apart. The goals and expectations of both departments should be more aligned. Once the goals are aligned it is important to evaluate the results periodically.

This paragraph has given some suggestions for interventions. Most interventions should be further explored through computer simulation or a more extensive data study. These studies could estimate the effect of the interventions and also give indications for possible drawbacks. Other interventions can be implemented in the process immediately, but the results should be monitored.

Chapter 4 Conclusions and recommendations

This chapter gives answers to the research questions and provides recommendations for improvement. These recommendations are only partly focused on changing the current situation, supplementary recommendations are about further research for improvements to come to a desired situation. The goals of this report were to give an insight in the process of pathology testing, the interaction between departments and avoidable activities. With this information we were able to make suggestions for possible interventions. A qualitative research has been done to answer the research questions and achieve the research goal.

4.1 Conclusions

Q1. How is the process of pathology testing organized?

In this research the process of pathology testing was analyzed via observations and interviews. Figure 6 shows an EPC with all the steps in the process, from the moment the blood is taken from the patient to the moment that the results are read out by the doctor.

Q2. Which stakeholders are involved in the process of pathology testing and what interests and powers do these stakeholders have? How can performance be quantified into KPIs?

In this research the stakeholders of the process of pathology testing were analyzed. Table 2 gives an overview of all the stakeholders and their salience class. The research was initialized to reduce the access block at the ED, consequently there is special attention to the interaction between pathology and ED. From interviews and observations of the main stakeholders their interests were retrieved. To measure the performance of the process of pathology testing and to show improvements after interventions we formulated key performance indicators in four different categories.

1. Waiting time
    - Average emergency room patient waiting time
    - Average outpatient waiting time
    - Percentage of tests that is completed within the given time frame
2. Quality
    - Percentage of pathology test results in errors, due to an incorrect result
    - Percentage of pathology test results in errors, due to an absence of desired data
3. Costs
    - Average costs per pathology test
4. Employee satisfaction
    - Average score on employee satisfaction surveys
    - Percentage of time devoted to primary activities

Q3. Which parts of the process of pathology tests create waste, variability or complexity and thereby cause waiting time for patients on the ED?

To increase the performance of the process of pathology testing, we sought for avoidable activities. These activities should result in a reduction of waiting time, an improved or at least stable quality, acceptable costs and an improvement in the employee satisfaction by increasing the part of their time spent on the primary process. The activities we looked for contained any form of waste as described by lean manufacturing. The activities with potential to be avoided were tested on their relevance and if it was realistic to avoid them. With the list of avoidable activities we were able to find a list of causes.

- Communication
    - No or inappropriate use of the IT system
    - Inappropriate use of the priority system
    - Inappropriate use of the classification system
    - Excessive telephone communication
- Logistic
    - No optimal allocation of samples
- Planning
    - Limited number of ward rounds
    - Unpredictability of outpatients

Q4. What interventions may reduce the waiting times for test results?

When the causes of avoidable activities are positively affected, it is possible to avoid those activities. We suggest interventions that positively influence the causes.

- Reduction of variability via planning: by planning of ward rounds and outpatient arrival, the number of tests over time can be more equal and in cases where this is not possible, the planning of resources can be optimized to reduce the influence of variability.
- Proper use of priority system: doctors and nurses should be explained what the priority level imply and the pathology staff should get instructions how to use the priority system.
- Training ED staff: ED staff should be trained how to optimally supply pathology.
- Better use of communication tools ED: agreement between ED and pathology about the way of communicating (abnormal) test results.
- Alignment of goals: the expectations of ED and the goals of pathology about turnaround time for tests and the percentage of tests that should be within the maximal time frame should be aligned.

We expect that the result of those interventions will have a positive impact on the performance of the process of pathology testing. The impact of these interventions need further data study to see the magnitude of the effect.

4.2 Recommendations

This last section of the report summarizes the recommendations and directions for further research.

We recommend to use the KPIs, as described in section 2.3.2., to measure the performance at this moment in time in order to have a baseline measurement. Much of this data is already available via the information system and some should follow from further research. In this way there is a benchmark possible with future performances and also with other pathology departments, from the SWAPS area for example. Best performances can be analyzed and used in other pathology departments as well. With the KPIs it is also possible to see the effect of changes in the process of pathology testing.

In section 1.5 the limitations of this research were explained. One of the major limitations was the lack of data. For the large research performed by the UWS, for which this is a preliminary research, we recommend that an extensive time study should be done. In such research all the activities should be analyzed and time spend on each activity should be measured. Interviews with personnel involved can be used to check the relevance and realism of avoiding the activity. This results in quantitative data to base the conclusion for avoidable activities on and an estimation of the time that can be saved. The causes of the activities with the most avoidable time can then be tackled. The KPIs can be used to see whether or not tackling a cause has the desirable effect.

To optimize the planning a more in-depth knowledge of the sources of demand is needed. It would be useful to know if there are certain times of the day that there is a large demand from one of the sources. Planning can then be used to either prevent the occurrence of this peak in demand or it can plan resources to deal with a peak in the most efficient way.

For the allocation of machines over the different departments and parts of the SWAPS area as well as for the operating hours of the pathology department we recommend to do a simulation study. There are several reasons why we recommend to use a simulation model. One reason is that it is a frequently used tool in lean system thinking. Another reason is that it can capture a complex system under a set of assumptions. In this way it can give a simplified description of the existing system. With simulation models alternative proposed system designs can be compared without really implementing these changes (Law, 2007). This has four advantage:

- It is possible to maintain more control over experimental conditions
- A study of the system for a long time can be performed in compressed time
- No need to experiment in the existing system
- It gives a visual reproduction of the existing system, which makes it allows to show the results even to someone with no knowledge of modelling or mathematics.

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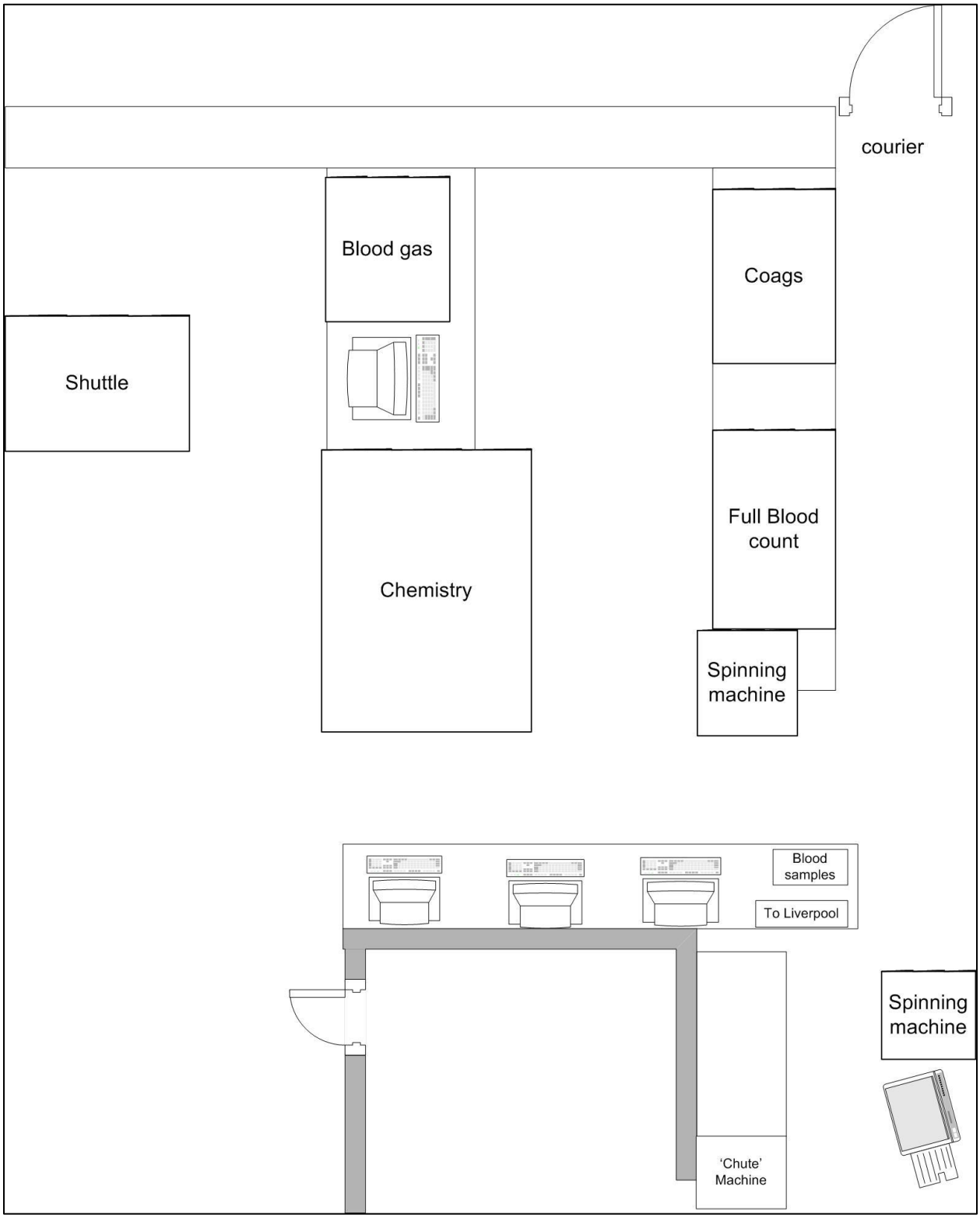
Appendices

1. Floor plan of the Pathology department



2. Overview of available machines

Common used name	Machine name	Possible tests	Maximum throughput	Start and end Time	Quality control
Full blood count	CELL-DYN Ruby (Hematology Analyzer)	- White blood cell parameters - Platelet parameters - Red blood cell parameters - Hemoglobin parameters	(close mode) 84 specimens/hour (open mode) 70 specimens/hour	Starts at: 7:20 AM Ends at: 00:00 AM	Every 2 hours from 08:00 am
Coags	Siemens Sysmex CA-530 (Coagulation Analyzers)	- PT (prothrombin time) - APTT (activated partial thromboplastin time)	54 specimens/hour	Starts at: 7:30 AM Ends at: 00:00 AM	Every 2 hours from 08:00 am
Blood gas	Siemens Rapidlab 1265 (Blood Gas Analyzers)	- PH - Blood gases - Electrolytes - Metabolites - Hemoglobin	25 specimens/hour	Has to be ready 24/7	*Automatic QC* - 08:00 am - 02:00 pm - 08:00 pm
Chemistry	Siemens Dimension Xpand plus (Clinical Chemistry Analyzers)	- EUC (electrolytes, urea, creatinine) - LFT (liver function tests) - CMP (Calcium, magnesium, phosphate) - CK (creatine kinase) - BHCG (beta Human chorionic gonadotropin) - Glucose level - Paracetamol level	76 specimens/hour	Starts at: 8:00 AM Ends at: 00:00 AM	- 08:00 am - 01:00 pm - 07:00 pm

Source: http://www.medcompare.com/