University of Southern Queensland

IDENTIFYING AND MINIMISING PREVENTABLE DELAY WITHIN THE OPERATING THEATRE MANAGEMENT PROCESS: AN ADAPTED LEAN THINKING APPROACH

A dissertation submitted

by

Gong, XiaoYan

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ABSTRACT

This study examines how preventable delay could be identified and minimised by using adapted lean thinking within the Operating Theatre Management Process (OTMP). The study uses the operating theatre of a regional hospital in Toowoomba (Queensland, Australia) as a case study. The theoretical framework for this study comprised socio-technical system theory and coordination theory. From the perspective of socio-technical system theory, each activity within the OTMP has two types of elements: social elements and technical elements. Coordination theory, on the other hand, considers the coordination between various elements of the activities. Time and motion study has been employed to analyse activities in terms of operation, transportation, delay and monitoring within the operating rooms. Subsequently, adapted lean thinking has been employed as an integrating approach to identify preventable delay and disruption within both value added and non-value added activities. Identifying preventable delay within the value added activities inside the operating room is one of the most important contributions of this study.

This research uses an exploratory qualitative case study. The focus of this research is to study activities inside the operating rooms, rather than the whole OTMP. Notwithstanding the limited time available to the researcher within a Masters degree, the study sought to establish the direct link of the activities inside the operating rooms with patients' waiting time.

Data were collected from 22 surgery cases through direct observations. In each surgery, the research team followed patient progress from the pre-operative holding area through to discharge. The researcher observed and recorded the timing of all the activities inside the operating rooms. As much detail as possible was observed and recorded to capture sufficient details to allow identification of problems. Moreover, initial observation results were verified and additional information was collected as necessary through communications and interviews with medical staff (surgeons, scrub nurses, technicians etc.) and review of documents.

The study indicates that coordination, motion economy, consent form, protocol policy, and surgeon preference sheets were the major areas impacting on preventable delay in the operating theatre suite activities. With the application of lean thinking, the results suggest that preventable delay and disruption within both value added and non-value added activities could be eliminated or minimized through better work organization, motion economy training and better coordination of tasks.

For further study, a benchmarking based study could be conducted to see if similar sets of preventable delay are observed in other healthcare institutions. In addition, examination of other related sections in a hospital is highly desirable to identify the wide range of preventable delay within the OTMP. This, in turn, will help to improve OTMP efficiency and, accordingly, reduce the waiting time of waiting lists.

CERTIFICATION OF DISSERTATION

I certify that the ideas, data, results, analyses and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award except where otherwise acknowledged.

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Signature of Candidate Date

ENDORSEMENT

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Signature of Supervisor Date

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LIST OF ACRONYMS

STS – Socio-technical system

CT – Coordination theory

VA – Value added

NVA – Non-value added

OTMP – Operating theatre management process

OTS – Operating theatre suite

OR – Operating room

PAH – Princess Alexandra Hospital

THS – Toowoomba Health Service

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CHAPTER 1 – INTRODUCTION

1.1. Background

The literature indicates that wasted time in hospitals impacts significantly on their expenditure and affects the quality of patient care (Tyler, Pasquariello & Chen 2003). As Harders et al. (2006) point out, improving the performance of operating theatres is the key to improving services for patients. More efficient use of operating theatres will reduce waiting times in patient treatment; however, process variation remains a major reason for poor performance within operating theatres. Process variation frequently arises from disruption and delay (Danovitch et al. 2002). These disruptions are often a result of lack of consistency between planned theatre session lists and the manner in which the task is actually carried out. Delays arise when procedures exceed scheduled time allocations, or when lists are altered to accommodate additional patients (Buchanan & Wilson 1996). Foote, Houston and North (2002) maintain that such delays and disruptions have substantial financial implications for hospitals, as well as affecting waiting lists, and are recognised as a growing problem throughout the developed world.

This study focuses on identifying preventable delays inside the Operating Rooms (ORs). Operating theatre management process (OTMP) is a complicated healthcare-delivery process starting from the referral of a patient to a hospital through to the discharge of the patient from the hospital after surgery has been performed (Al-Hakim 2006). Waste—that is, disruption and delays—are major aspects this study however, while the complexity of operations may increase surgery session time, it does not cause the surgeon to wait. Therefore, the level of complexity of operations was not expected to significantly influence disruption and delay.

The concept of lean thinking is applied in this study. The concept was introduced by Toyota in Japan as a systematic approach to identifying and eliminating waste or non-value-adding (NVA) activities in an organization through continuous improvement with value added (VA) activities (Womack & Jones 1996). It is a paradigm that advocates improving efficiency of business, while meeting the demands of customers effectively (Jones & Mitchell 2006; Womack & Jones 1996). The application of lean thinking in healthcare may, therefore, produces beneficial results. The literature describes how the concept can be applied in healthcare (Jones & Mitchell 2006; King, Ben-Tovim & Bassham 2006b).

In contrast to a manufacturing environment, healthcare services are fully customised in which each object (patient) has unique features and health status (De Koning et al. 2006). In addition, healthcare services often impose unanticipated deviation from planned activities resulting from the unpredictability of patients' behaviour, high degree of variability and unexpected emergency events (Brock 2007; Ettinger 2006). Subsequently, given its origin in manufacturing, lean thinking needs to be adapted for successful implementation in healthcare settings. Therefore, this study aims to examine the application of lean thinking concepts within the operating theatre management process.

1.2. Motivation

Generally, hospitals are not implementing the necessary improvements in cost, quality, and safety to improve the outcomes in these key areas. More than half of the 670 hospitals recently reviewed by the Australian Council of Healthcare Standards (ACHS) had inadequate quality control systems for patient safety (Scott, Poole & Jayathissa 2008). The current organization and management of hospitals is an imperfect system that does not effectively address these issues (Bowman et al. 2003). Moreover, major projects to restructure hospitals, dramatically reduce cost, and improve patient care have had little impact on quality or cost (Bowman et al. 2003). The motivation for this study mainly emanates from this perceived need for improving healthcare services. It is argued in the study that the application of lean thinking within hospitals can provide a solution to successfully address some of these concerns with minimal cost, but maximum benefit.

1.3. Research questions

This study aims to address the following general research question (RQ):

RQ: How can non-value added activities be identified and reduced using adapted lean thinking within the operating theatre management process?

To answer the general research question, the following sub-questions (SQ) were addressed:

SQ1: How can non-value added activities be identified in an operation room?

SQ2: How can preventable delay in the value added activities be identified in an operation room?

SQ3: What are the major causes of delay and disruption in an operation room?

SQ4: How can the surgery session time be reduced?

These sub-questions served as a guide for the investigation to adequately address the general research question. The OTMP was broken down into its sub-processes and activities. This enabled the researcher to gain initial information from the operating theatre, the major part of which is Operating Rooms (ORs). Personal communication with the liaison officers of the case hospital indicates that delay and disruption outside OR are usually reported. Thus, this study focused on identification and elimination of non-value added activities and delays inside OR, based on the concept of lean thinking. To address the first sub question, the non-value added activities within the OR were identified. The second sub-question served as a guide to identify the preventable delay within the value added activities. Similarly, the third sub-question was addressed to identify the causes of disruption and delay in OR. Through the fourth sub-question, the study demonstrated how overall surgery time could be reduced with elimination of non-value added activities.

1.4. Research methodology

The study employs an integrated theoretical framework made up of coordination theory and socio-technical systems theory. Motion and time study was employed as a tool to identify mechanisms to make body motion and work organization more efficient. The concept of lean thinking was then employed as an integrative concept to evaluate the practices in the OR from the perspective of identifying and minimizing non-value adding activities. A case study methodology has been employed in which data were collected primarily through direct observation of surgery cases and additional data were collected with interviews and review of documents.

1.5. Scope of the study

The scope of this study is restricted to the application of the concept of adapted lean thinking in a healthcare setting. The study did not aim to develop a model for a healthcare setting; instead, the existing lean thinking concepts were adapted to fit a healthcare setting.

1.6. Key definitions

Operating theatre management process (OTMP): a complicated healthcare-delivery process which starts from the referral of a patient to a hospital that ends with the patient's discharge from the hospital after surgery has been performed.

Operating Theatre Suit: part of OTMP that comprises all areas related directly to the surgical procedures from pre-operative function to recovery area.

Pre-operative holding area is designed to accommodate the admission of patients before entering the OR.

Anaesthetic bay is the area within the OR where the patient is assessed and prepared for anaesthesia.

Recovery area is situated near the entrance of the operating theatre suit. There are eight bays commissioned within the unit. The post-operative patient is closely monitored until they are physiologically stable.

Sterile stock room is centrally located in the operating theatre suit; reusable and disposable sterile supplies are stored in this area.

Surgeon's preference sheets: the surgeon's specific preferences and any variance from the procedures in the procedure book are noted on these sheets. The sheets are revised as procedures and personal preferences for new technology change.

Consent form: the form requires patient's consent on patient's condition and procedure, surgery and treatment plan. It also includes statements about risks and complications.

Anatomy area: the area when the incision takes place.

Mayo table: The table used in a sterilised area to lay down frequently used instruments and other materials during the surgery.

Patient positioning: the position of the patient during the surgery.

Surgeon: physician who performs the surgical procedure.

Assistant surgeon: member of sterile team who provides exposure and hemostasis during a surgical procedure.

Anaesthetist: member of the non-sterile team who administers anaesthetics during the surgical procedure.

Scrub nurse: member of the sterile team who passes instruments and facilitates the surgical procedure.

Scout nurse: member of the non-sterile team who directs and coordinates the activities of the intra-operative environment during the surgical procedure.

1.7. Limitation

Despite the several contributions that this study is expected to make, some limitation of the study should be noted. Firstly, only one hospital has been used for observation of surgeries. Although similarity is expected among different hospitals in the management of operating theatres (Foo 2006), there could be variations in the level of efficiency of operations. Secondly, only 22 surgeries—selected on a random basis—were observed, thus, the observed cases may not represent the thousands of surgeries undertaken in the hospital. Different surgeons were observed in each of the cases included in this study and the liaison officer chose the days in each week and then randomly selected the surgery cases to be observed. Thirdly, the study was based on observations in the operating room, rather than the whole operating theatre process. Finally, the presence of the researcher as an observer may lead the OR team members to alter their behaviour knowing that they were being observed; hence all the possible inefficiencies may not have been observed.

1.8. Importance and contributions of the study

As higher healthcare costs appear to be an increasing trend, healthcare providers and hospitals in particular are under continuous pressure to dramatically improve service, reduce costs, improve patient safety, reduce waiting times and reduce errors and associated litigation (Scott, Poole & Jayathissa 2008). They need to streamline their organization systems and processes to fully support the process required to deliver high quality care. There are several successful lean thinking projects in healthcare services relating to reduction of waste and smooth flows of activities (Ahluwalia & Offredy 2005; De Koning et al. 2006; Jimmerson, Weber & Sobek 2005; Jones & Mitchell 2006; King, Ben-Tovim & Bassham 2006). Nonetheless, it appears that there has been limited prior research that dealt with the causes of disruptions and delays within the operating room (OR). The present study is expected to contribute valuable insights to the literature, as well as to healthcare services management.

In addition, this study is expected to contribute to the empirical literature by differentiating NVA activities and VA activities in operating rooms. It will also identify the bottlenecks that are detrimental to the smooth movement of patients and information. Further, the results of the study are expected to contribute to the theoretical literature as they could be used to demonstrate how lean thinking can be applied in a non-manufacturing setting.

1.9. Structure of the thesis

The remaining chapters of the thesis are organised as follows (see Figure 1.1).

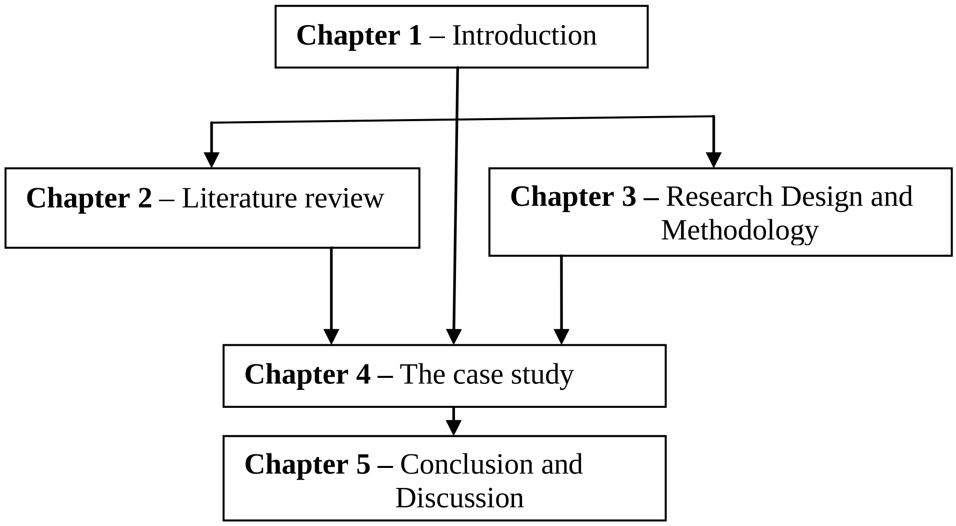


Figure 1.1: Organization of the thesis

- Chapter 2 provides a review of the literature that served as a basis for the thesis. It explains OTMP, including the ORs. It also discusses the concepts and tools and theories employed in the study. Specifically, time and motion study, coordination theory, socio-technical systems theory, and lean thinking are reviewed.

- Chapter 3 discusses the research design and methodology. It explains the theoretical framework of this study followed by a description of the research methods in terms of the data collection instruments and procedures, as well as the choice of the cases study methodology.

- Chapter 4 reports the analysis of the case study whereby the details of the information collected from the hospital are examined and then used to draw major findings. The chapter presents the data collected via observation of the surgery cases, interviews and review of relevant documents. It then identifies the major non-value added activities, their causes and effects, and the recommended courses of action to eliminate non-value added activities.

- Chapter 5 concludes the thesis. It includes a summary of the thesis, its findings and a discussion on how well the research questions have been answered. It also provides directions for future research.

1.10. Summary

This chapter has presented both the background and the motivation for the study and the research questions. The chapter also provided the research questions and the delimitations of the study, as well as its importance and contribution to the field of study. In conclusion, the chapter provides the structure of the remainder of the thesis. The following chapter presents a review of the related literature.

CHAPTER 2 - LITERATURE REVIEW

As briefly alluded to in Chapter 1, wasted time in hospitals is increasingly becoming a significant concern to healthcare institutions and is affecting the quality of patient care. Some institutions in the healthcare industry have recognised that elimination of non-value added activities as a precondition for provision of quality healthcare services at a reasonable cost. To continuously reduce the high levels of disruption, delay and other non-value added activities, their causes and possible solutions need to be charted out. This chapter reviews the literature on operating theatre management process in a combined framework of socio-technical system theory and coordination theory employing adapted lean thinking as an integrating concept to eliminate wasted time in the operating room. The following section describes the operating theatre management process, followed by an explanation of lean thinking. Section four discusses time and motion study; and section five discusses socio-technical system theory and coordination theory. Section six explains the need to adapt lean thinking in a healthcare setting and shows how it could serve as an integrating strategy. Section seven follows and identifies the gap in the literature and, finally, section eight summarizes the chapter.

2.1 Operating theatre management process

In recent years there has been an increase in waiting lists in hospitals, which has led to an enhanced understanding in the sector of the need to minimise wasted time, and to improve patient care. Operating theatres use a significant proportion of the total resources of hospitals (Bleakley 2006; Cookson et al. 2005; Harper 2002). From the point of view of operations management, a hospital can be described as a network of service units with finite capacity through which patients are flowing (Gemmel & Van Dierdonck). A patient can be scheduled for surgery interventions either as an outpatient, or as an inpatient (Adan & Vissers 2002). An outpatient is admitted after a referral from a medical professional or from other hospitals; whereas inpatients' admission can be divided into scheduled and non-scheduled admissions. Scheduled inpatient admissions or elective patients are selected from a waiting list or are given an appointment date. Non-scheduled inpatient admissions, also known as emergency admissions, concern patients that are immediately admitted to the operating theatre from the emergency department (Hodge 1999; Vissers, Adan & Bekkers 2005). Patients for elective surgery can be classified into day-only surgery or day-of-surgery.

Operating theatre management process (OTMP) is a complicated healthcare-delivery process which starts from the referral of a patient to a hospital that ends with the patient's discharge from the hospital after surgery has been performed (Al-Hakim 2006). OTMP can be classified into operation-based or management-based. The former divides OTMP into several operations: preadmission, booked admission, assessment, perioperative procedures, intra-operative management and discharge (Healey, Sevdalis & Vincent 2006; Michaloudis et al. 2006; National Health and Medical Research Council (Australia) 1996; Pandit & Carey 2006; Pandit, Westbury

& Pandit 2007; Rafferty et al. 2006; Yule et al. 2006). On the other hand, management-based classification includes capacity management, waiting list management, and information flow management. Capacity management is further divided into bed management, operating management and nurse management (Cheng & Newman 2005; Everett 2002; Hodge 1999; Inputs et al. 2000; Lewis et al. 2004; Morton 2005; Onslow 2005; Pearson et al. 2004; Proudlove & Boaden 2005; Reason 2000).

2.1.1 Operation-based OTPM

Preadmission assessment

Pre-admission assessment is essential for elective surgical patients. It includes the pre-registration process, chart preparation and appointments, performance of general secretarial and clerical duties for the organization and maintenance of the medical record, and provides effective communication between departments, physicians, patients and families. Benefits of pre-admission assessment include: accurate information is obtained about the patient, thus identifying potential risks; decreased patient cancellations; patients are better informed of their surgery; and it decreases late preparation for elective surgery (Foo 2006).

Booked admission

Booking will give all patients a choice of a convenient admission date within a guaranteed maximum waiting time. Booked appointments are the key to improving patient convenience (Walker & Haslett 2000). Admission scheduling is part of an admission process which starts with the generation of a demand for admission and ends with the effective admission of the patient. Scheduling admissions is performed within a framework of many different, and sometimes contradictory, goals and include: high utilization of the available capacity; smooth throughput resulting in a minimal length of stay; and customer service, where the patient, as well as the physician, may be defined as customers. When discussing these goals, it is important to recognize that several agents, such as patients, specialists and the chief executive officer, are involved in the admission process (Al-Hakim 2007; Gallivan et al. 2002).

Assessment

Although ensuring medical fitness for surgery is a vitally important activity, pre-assessment skills could be widely viewed as medically-oriented tasks designed to ensure both surgical safety and the progressive throughput of patients in the limited time available (Pandit & Carey 2006).

Perioperative

Perioperative processes include the activities of patient booking, operating scheduling and patient preparation. It consists, according to Lancaster (1997) of:

- expanding the scope of perioperative care to include all activities from the hospital receiving the Recommendation for Admission Form to discharge from either the day-only or recovery unit.

- an expanded scope of responsibility—bundling of activities with responsibility delegated to an individual to enable new processes to occur.
- a collection of related activities, such as booking and scheduling with the pre-admission clinic for day-only and day-of-surgery unit located adjacent to the operating theatres.
- real time data and information.

Preoperative assessment is often coupled with preoperative education for the patient. This education may be presented in a variety of ways including one-on-one consultations, tours of facilities, group meetings or telephone consultations. The aim of preoperative education is to decrease anxiety preoperatively, assess patient and family learning needs, and to individualise information for each patient (Lancaster 1997).

Intra-operative management

The intra-operative activities involve managing operating theatre resources and procedures directly associated with the surgery to ensure safe and effective patient outcomes. It also includes the preparation of operating room lists. Cancellation of surgery by patients without adequate notice is the main problem of intra-operative management. Non-attendance by patients for elective surgery, with insufficient time to find replacement, leads to wasted theatre time and wasted resources (Dingle et al. 1993). Previously published studies have suggested that a significant number of these cancellations could be reduced by the introduction of pre-admission clinics (Sanjay et al. 2007). The use of such clinics has also been shown to increase the number of same day surgical admissions, thus further reducing the use of surgical beds (Van Klei et al. 2002).

Discharge

To achieve a high-quality service, discharge planning in day surgery should begin before the adult or child is admitted to the unit. Pre-operative assessment has become essential to the development of day surgery planning. For children and adults alike it provides an opportunity to discuss the patient’s needs and to address any fears or anxieties of the patient, family or carer. Discharge planning must embrace physical, psychological and social aspects of individual patient care. This framework can then be used to develop guidelines for patient discharge following day surgery.

2.1.2 Management-based OTMP

Capacity management

Capacity management is the capability of the system to admit the appropriate patients when necessary, provide the appropriate treatment in a suitable environment, and discharge as soon as appropriate (Al-Hakim 2007). While scheduling admissions it is not only important to match capacity of resources and demand, it is equally important to match the capacity of one resource with the capacity of other resources. The type of resources required in a hospital, and the subject of this research is beds, nursing capacity and operating room capacity. These resources are used together for the treatment of a particular patient (Vissers 1995). In other words, fluctuation in the utilization pattern of one resource leads to fluctuation in the utilization pattern of another resource. Furthermore, limitations on the capability of one resource to serve patients have an impact on the service capacity of other resources. There are decisions to be made both as to which patients will be admitted to the unit, and when a particular patient will be admitted (Kim et al. 1999). An admission policy based on workload indices on nursing units provides for dissimilarities in patients (Offensend 1972), provides a stable workload pattern within a nursing unit, and equitably distributes the work among the units (Shukla, Ketcham & Ozcan 1990). When operating room capacity is ignored in the admission schedule, the scheduling system fails to consider the variation in operating room time required by the cases (Magerlein & Martin 1978).

a. Bed capacity

Bed capacity can be defined as a balance between flexibility for admitting emergency patients and high bed occupancy (Fletcher & Hodges 1999). However, deciding on just how many beds to provide is not a simple decision—there are a number of complicating factors which mean that this kind of simple calculation is inappropriate (Ridge et al. 1998), including:

- Emergency patients arrive randomly, often in quick succession, and must be admitted with a minimum of delay. The build up of 'emergency queues' and the need to transfer patients to other hospitals is highly undesirable.
- Elective patient admissions are subject to the constraints imposed by other hospital services, such as surgeons' hours and theatre space, and the number of free beds in the hospital.
- Elective patient admission profiles can be highly correlated with the time and day of the week.
- Patients' length of stay is frequently distributed with a bias towards shorter, rather than long, stays. Sometimes, however, a patient will stay a very long time, which can cause a disproportionate 'blocking' effect in the hospital with respect to subsequent referrals.
- Different patient types have different LOS distribution profiles.

These features point towards the need for sophisticated bed capacity planning models from the discipline of operational research. Simply increasing supply is not good enough in the medium term. Most hospitals desperately require more beds, but they also need to use their existing beds more efficiently—thereby improving patient experience and avoiding the possibility of further inferior performance by injecting more resources into an already chaotic system. Some commentators believe this need not be an expensive exercise, indeed, international comparisons suggest it should be possible for the National Health Service to perform better at less cost (Boaden, Proudlove & Wilson 1999).

b. Nurse capacity

The role of the nurse during anaesthesia and surgery is one that has interested health service managers keen to know what happens behind the closed doors of the operating department. It is clear that if nurses working within this specialized setting are to secure a future in providing care for surgical patients, then it is important to clarify and articulate exactly what it is that their role involves (McGarvey, Chambers & Boore 2002).

c. *Operating room capacity*

Adan and Vissers (2002) indicate that effectively managing and utilising operating theatre capacity is essential to enhanced outcomes. Operating room lists are drawn from the surgery waiting list for scheduling in the operating theatre on a certain day or session. Once drawn up, theatre lists are unprotected in that they are subject to alteration and renegotiation, owing to cancellations and the addition of emergency, urgent and priority cases which create theatre-running and list-rescheduling problems. The prior allocation of priority and emergency theatre sessions has not overcome these problems. There are, in addition, a number of operating theatre department factors which lead to disruption and delays, which are discussed below.

Waiting list management

Waiting times and waiting lists are important issues for healthcare, as long waiting lists have become symbolic of the inefficiency of hospital services worldwide, particularly in publicly-funded hospitals. Issues of long waiting lists are often used by governments as part of their reform program, or by political parties to attack governments. This can be seen in how often waiting lists form headlines in newspapers nowadays. Problems of increasing hospital waiting lists are regularly highlighted and pressure is often applied to governments to take action to remedy the situation. Waiting list can be classified into elective and non-elective surgery. Under elective surgery, there is day surgery and day-of-surgery. There is a wide range of non-emergency surgical operations that can be carried out as day surgery and this has considerable advantages for patients, as well as the hospital. Over-running operating lists are known to be a common cause of cancellation of operations on the day of surgery and Buchanan and Wilson (1996), in their research, investigated whether lists were overbooked because surgeons were optimistic in their estimates of the time that operations would take to complete.

Information flow management

Patient satisfaction surveys indicate that many patients felt that information provided prior to surgery was inadequate and failed to meet their needs in terms of preparing them for what to expect from the operation itself, and admission care and discharge. Administrative staff feel isolated and uninformed, despite the significance of their activity in supporting the patient flow. There is a considerable volume of performance information available, for example, with regard to patient flow through theatres. It is only recently that this information has been systematically captured and disseminated and, thus, been made available to inform clinical and managerial decisions. There would, therefore, appear to be some potential for continuous improvement in pursuing the effective use of management information (Buchanan 1998; Buchanan & Wilson 1996).

The focus of the present study is the operating room (OR) of the operating theatre as there appears to be a dearth of prior research in this particular area. The following sections discuss the theories and concepts employed in the present study to identify non value added activities and to recommend possible solutions to minimize these activities.

2.2 Time and motion study

Time and motion study originated with the works of Frank B Gilbreth (1868-1924) and Lillian Moller Gilbreth (1878-1972). Motion study entailed the detailed examination of the movements of individual workers made in the process of carrying out their work. The notion of work simplification was based on respect for the dignity of people and work, and was developed by Frank Gilbreth from the age of seventeen, when he began work as a bricklayer (Chartered Management Institute 2000).

Time and motion studies were initially used to enhance efficiency. The combination of the two techniques evolved into time and motion study and increased in popularity in the 1930s. Time and motion studies are applied to reduce the number of motions in performing a task so as to increase productivity (Barnes 1980). Ralph (1980, p. 6) defines motion and time study as follows:

> Motion and time study is the systematic study of work systems with the purposes of (1) developing the preferred system and method—usually the one with the lowest cost; (2) standardising this system and method; (3) determining the time required by a qualified and properly trained person working at a normal pace to a specific task or operation; and (4) assisting in training the worker in the preferred method.

Ralph's (1980) definition embodies important dimensions of motion and time study. First, motion study (work method design) aims to identify the design of a system and the sequence of operations and procedures that make up the preferred solution. Second, once the process or job has been designed, the system should be broken down into each specific activity and specified into a particular set of motions, as well as the size, shape, and quality of material, equipment and tools required to execute the activity. This second process is standardization. Therefore, time and motion study is the systematic study of work systems with a view to developing an allowed time standard to perform a given task, based upon measurement of work content of the prescribed method with due allowance for fatigue and unavoidable delay. It also involves analysing the various body motions employed in doing a job for the purpose of eliminating ineffective movements and speeding up effective movements (Barnes 1980; Kettinger, Teng & Guha 1997).

2.2.1 Process analysis under time and motion study

Henry Gantt developed the ideas that grew into what came to be known as the `Gantt chart', which is a system of recording the planning and control of work in progress (Chartered Management Institute 2000). Frank and Lillian utilised a Gantt chart in their work and they added process charts and flow diagrams. These new tools graphically demonstrated the constituent parts that need to be carried out to complete a task. Barnes (1980) indicated that before studying each and every step in a series used to complete a process or an activity, it is useful to consider the entire system. In an operating theatre setting, this means that all the steps within the operating theatre should be considered in relation to each other. In handling the patient from admission to final discharge, it is essential that each and every phase of the series of steps in the overall picture be considered, making no assumptions. The literature indicates that standardised symbols are employed in undertaking time and motion study. Table 2.1 presents a breakdown of the basic work elements defined by Gilbreth (1921). They used four basic symbols: a circle for operation; a square for inspection; an inverted triangle for storage; a block arrow for transportation. The symbol “D” is sometimes used to distinguish a delay from storage.

Table 2.1: Basic work elements

Operation (Doing work) – An operation occurs when an object is intentionally changed in one or more of its characteristics. An operation represents a major step in the process and usually occurs at a machine or work station.

Transportation (Moving work) – transportation occurs when an object is moved from one place to another, except when the movement is an integral part of an operation or an inspection.

Inspection (Checking work) – An inspection occurs when an object is verified for quality or quantity in any of its characteristics.

Storage/Delay (Nothing happening) – storage occurs when an object is kept and protected against unauthorized removal. A delay occurs when an object waits for the next planned action. (A “D” symbol is sometimes used to distinguish a delay from storage.)

Source: Adapted from Barnes (1980, p. 73)

The tabular map (Table 2.2), adapted from Barnes’ (1980) time and motion study book, illustrates various categories of activities—Transportation (→), Delay (D), Monitoring (□) and Operations (O) as representing the status of the object. It also shows the distance (Dist) between two processes: the time spent to achieve the activity. The chart might begin with the first entry on the form and show all the steps until the form is permanently filed or destroyed.

Table 2.2: Tabular form of process map

Dist	**Time**	**Chart symbols**				**Process description**
		→	**D**	□	O	
		→	**D**	□	O	
		→	**D**	□	O	

Source: Adapted from Barnes (1980)

The process of analysis has been successfully applied to a job or number of jobs to check the efficiency of the work method, equipment used, and the worker in manufacturing. However, there are some differences when it is used in a hospital setting, thus, there is a need to closely examine its application in healthcare.

2.2.2 Application of motion and time study in hospitals

Time and motion study has a wide range of applications today (Burguer 2008), including the application in operating theatres in hospitals (Burguer 2008; Leedal & Smith 2005). Through proper application of the principles of time and motion study, surgeons should be able conduct their work efficiently and prevent waste of their precious time (Chartered Management Institute 2000). The importance of efficiently managing activities in the OR has generally been well recognized. Atkinson and Kohn (1986) propose the use of time records of activities to determine efficiency and to identify the quickest and easiest ways of doing things. As Atkinson and Kohn (1986, p. 190) comment:

> Time is an important element in the OR. If time is wasted between operations, for example, the day's schedule is slowed down and later operations are delayed. The surgeons' time is wasted and they tend to come late, anticipating delays. The patients become more nervous waiting for their operations and more uncomfortable during the prolonged period without fluids.

Leedal and Smith (2005) analysed the components of anaesthetists' operating room activities, and the factors contributing to workload, using an ergonomic-based model for technological environments. Den Boer et al. (1999) applied standardised time-motion analysis to evaluate the preoperative surgical process which provided detailed insight into the preoperative process of the surgery, thus leading to improvements in the surgical process and instruments used. Recently, Wallace & Savitz (2008) chose time-and-motion methods to allow a description of low-frequency events and problems encountered in the US health care system.

Inside the OR, a body of knowledge commonly referred to as principles of motion economy has been in use for many years (Atkinson, 1992). Motion economy principles embody three categories of principles: body movement, arrangement of work places and design of tooling and equipment. As the first two categories are relevant for the present study, 16 principles of time and motion study in the first two categories are discussed next. The first nine of these principles concern the use of the human body, whereas the remaining seven principles relate to arrangement of the workplace.

1. *The two hands should begin as well as complete their motions at the same time.*
2. *The two hands should not be idle at the same time except during rest periods.*
3. *Motions of the arms should be made in opposite and symmetrical directions and should be made simultaneously.*

The first three principles are related because they all relate to movement of hands (Barnes 1980). There is a natural tendency for most people to use their preferred hand (either right hand or left hand) to accomplish most of the work and to relegate the other hand to a minor role, such as holding the object while the preferred hand works on it. The first principle states that both hands should be used as equally as possible, thus it would be necessary to design work methods such that the work is evenly divided between the two hands. The work method should be designed to avoid periods when neither hand is working. It may not be possible to completely balance the workload between the right and left hands, but it should be possible to avoid having both hands idle at the same time. When possible, symmetric and simultaneous motion minimizes the amount of hand-eye coordination required by the worker. And since both hands are doing the same movements at the same time, less concentration will be required than if the two hands had to perform different and independent motions. The need for economy of effort in an operating theatre and reducing fatigue in an operating room setting has been widely recognized (Burguer 2008).

When interpreted from the point of view of an operating room, the scrub nurse, for example, when she is using her left hand to pass the tool to surgeon, can use the other hand at the same time to collect the tool that is no longer used by surgeon. The tools or instrument should be divided in two sides: one for the tools that are going to be used, and another side for the tools that are going to be collected. It is better to use both hands equally in order to improve the performance and allow smoother coordination with the surgeon. In addition, the preferred hand is faster, stronger, and more practical. If the work to be done cannot be allocated evenly between the two hands, then the method should take advantage of the worker’s best hand. For the surgeon, for example, the patient should be positioned on the side of the surgeon’s preferred hand. The reason is that greater hand-eye coordination is required to initially access the patient; so the surgeon should use the preferred hand for this element (Philips 2004).

Regarding the second principle, the exception within the operating room is during the actual operation by the surgeon, when the rest of the staff are in a monitoring role and are using their cognitive senses rather than their hands. The scrub nurse, in her role of assisting the surgeon should, for instance, be able to notice the ongoing requirement from the surgeon in order to avoid the surgeon having both hands idle during the surgery (Philips 2004).

4. *Hand and body motions should be confined to the lowest classification with which it is possible to perform the work satisfactorily.*

Short motions are more effective than lengthy ones. There are five classes of hand motion (Barnes 1980, p. 186), namely:

1. Finger motions.
2. Motions involving fingers and forearms.
3. Motions involving fingers, wrist, and forearm.
4. Motions involving fingers, wrist, forearm, and upper arm.
5. Motions involving fingers, wrist, forearm, upper arm, and shoulder.

The motion first listed above requires the least time and effort. Thus, the work should be designed such that tools are near their point of use to enable short motions (Barnes 1980). The principle is applicable in a healthcare setting in that it helps reduce fatigue and, thus, enhances efficiency (Burguer 2008).

5. *Momentum should be employed to assist the worker wherever possible, and it should be reduced to a minimum if it must be overcome by muscular effort*

Momentum, which can be defined as mass multiplied by velocity, assists easy movement of motion if used appropriately. For the most part, in work that involves moving an object, the total weight moved by an operator includes the weight of the material moved and the weight of the part of the body moved. When the object to be moved is on the right momentum, it is advantageous to utilize it to move the object to the right target. When the momentum needs to be stopped, it takes some effort from the muscle of the operator to stop it. Thus the work should be designed such that the movement of objects enables the use of momentum and avoidance of unnecessary momentum (Barnes 1980). Not all work situations provide an opportunity to use momentum. Yet, as the general necessity to minimize physical stress in operating room activities is well recognized (Burguer 2008), the importance of this principle in OR, whenever possible, is evident.

6. *Smooth continuous curved motions of the hands are preferable to straight line motions involving sudden and sharp changes in direction.*

It takes less time to move through a sequence of smooth continuous curved paths than through a sequence of straight paths that are opposite in direction, even though the actual total distance of the curved paths may be longer, i.e. although the shortest distance between two points is a straight line. The reason behind this principle is that the straight-line path sequence includes start and stop actions that consume the operator's time and energy (Barnes 1980). This principle could apply to a surgeon's hand motion and could be implemented to make the activities of the surgeon more efficient (Burguer 2008).

7. *Ballistic movements are faster, easier and more accurate than restricted (fixation) or controlled movements.*

Ballistic movements (e.g. akin to when a carpenter swings a hammer in driving a nail) rather than fixation movements should be used whenever possible. Ballistic movements are less fatiguing, faster, and more effective. In ballistic movements, the body muscle contracts only at the beginning and will relax afterwards (Barnes 1980). In a similar way to the above principle, this principle could apply to surgeons' and nurses' movement of tools to make activities more efficient (Burguer 2008).

8. *Work should be arranged to permit an easy and natural rhythm wherever possible.*

Rhythm refers to regular sequence of similar motions. Basically, the worker learns the rhythm and performs the motions without thinking, much like the natural and instinctive motion pattern that occurs in walking. Whenever possible, the work should be designed such that rhythmic motion should be applied (Barnes 1980). The importance of proper work design in operating rooms enhances efficiency of operations and reduces mental and physical stress (Burguer 2008). The principle is especially relevant for nurses and wardsmen who perform repeat tasks.

9. *Eye fixations should be as few and as close together as possible.*

Where hand-eye coordination is required in a work situation, the eyes are used to direct the actions of the hands. Since eye focus and eye travel each take time, it is desirable to minimize, as much as possible, the need for the worker to make these adjustments. Eye travel occurs when the eye must adjust to a line-of-sight change—for example, from one location in the workplace to another, but the distances from the eyes are the same. Since eye focus and eye travel each take time, it is desirable to minimize, as much as possible, the need for the worker to make these adjustments. For example, in a health care setting, this can be accomplished by minimizing the distances between objects (e.g., patient and instruments) that are used in the operating room (Barnes 1980; Burguer 2008; Leedal & Smith 2005).

10. *There should be a definite and fixed place for all tools and materials.*

The worker will be more efficient when there is a defined place for materials and equipment. Definite stations for materials and tools enable the worker to develop a habit that helps rapid development of automaticity. If the workplace is arranged as such, the worker can perform the tasks with little conscious mental effort (Barnes 1980). Burguer (2008) indicates that efficient design and set up of operating rooms has long been a subject of interest to surgeons and that the optimum design characteristics and the design of standards have been widely discussed. As the saying goes, "a place for everything and everything in its place" is essential in an operating room environment. For example, if sharp instruments and used sponges are scattered randomly around the anatomy area of surgery, it would reduce efficiency and increase risks. This principle could be used to design a fixed location, allowing surgery and scrub nurses to reach for the instruments without wasting time by looking and searching.

11. *Tools, materials, and controls should be located close in and directly in front of the operator.*

Locating tools, materials, and controls close to and directly in front of the operator helps to minimize the distances the worker must move (travel empty and travel loaded) in the workplace. In addition, any equipment controls should also be located in close proximity. It is generally desirable to keep the parts and tools used in the work method within the normal working area, as defined for each hand and both hands working together (Barnes 1980). Arrangement of surgery instruments within the grasp of the surgeon is a typical application of this principle (Burguer 2008). The change of a surgeon's body position is not only time consuming, but also raises the risk to the patient. If the method requires the scrub nurse to move beyond the maximum working area, then the worker must move more than just the arms and hands. This expends additional energy, takes more time, and ultimately contributes to greater worker fatigue.

12. *Gravity feed bins and containers should be used whenever possible.*

Bins with sloping bottoms enable the item to be fed into the front with the help of gravity. A gravity fed bin is a container that uses gravity to move the items in it to a convenient access point for the worker (Barnes 1980). Designing equipment in operating rooms in a way that reduces physical stress could greatly enhance efficiency (Burguer 2008).

13. *Use gravity drop chutes (channels, tubes) for completed work units where appropriate*

The drop chutes should lead to a container adjacent to the worktable. The entrance to the gravity chute should be located near the normal work area, permitting the worker to dispose of the finished work unit quickly and conveniently. They are most appropriate for lightweight work units that are not fragile (Barnes 1980). Similar to the preceding principle, this principle enables minimization of physical stress which, in turn, is expected to substantially improve efficiency (Burguer 2008).

14. *Materials and tools should be located to permit the best sequence of motions.*

Items should be arranged in a logical order that matches the pattern of work elements. The items that are used first in the cycle should be on one side of the work area; the items used next should be next to the one that precedes it; and so on. If items are located randomly in the work area, that increases the amount of searching required and detracts from the rhythm of the work cycle (Barnes 1980). The need for proper arrangement and organization of tools and material in operating rooms for enhanced efficiency of operations has long been recognized (Burguer 2008).

15. *Provide for adequate visual perception. Good illumination is the first requirement.*

Proper illumination assists adequate perception, thus, light of the right intensity and colour, and that is without glare, should come from the right direction to the work area (Barnes 1980). In an operating room, for example, proper positioning of the patient and the application of mechanical retractors to the anatomy area greatly enhances efficiency (Burguer 2008).

16. *Arrange the height of the workplace and chair for alternate sitting and standing, when possible.*

This usually means an adjustable chair that can be fitted to the size of the worker. The adjustments usually include seat height and back height. Both the seat and back are padded. Many adjustable chairs also provide a means of increasing and decreasing the amount of back support. The chair height should be in proper relationship with the work height (Barnes 1980). This principle is highly applicable in an OR setting as there is a need to have a surgeon's chair that is adjustable in size.

2.3 Lean thinking

The lean thinking strategy is considered to have the capacity to enable delivery of better healthcare at the lowest overall cost (Jones & Mitchell 2006). Lean thinking originated in the Toyota Production system in the 1950s, and has been further developed by Womack and Jones (1996) (Balle & Regnier 2007; Young 2005; Young et al. 2004). The aim of lean thinking is to provide what the customer wants, quickly, efficiently, and with little waste. Thus, the concept of lean thinking is a paradigm that advocates improving efficiency of businesses, while meeting the demands of customers effectively (Jones & Mitchell 2006; Womack & Jones 1996; Young et al. 2004). It embodies five concepts:

Value – the company should design its product or the service with the customer in mind, i.e., what the company supplies should meet customers' expectations in terms of quality and price.

Value stream – all processes in the value chain should eliminate all types of waste. All activities in the value chain need to be those that add value to the customer.

Flow – The system should be designed in such a way that there is no intermediate storage of raw and semi-processed materials.

Pull – Each process should produce the demands in line; the process must be flexible and be geared to individual demands—producing what customers need when they need it.

Perfection – production of products or services should aim for perfection. Lean thinking creates an environment of constant review, emphasising suggestions from the 'floor' and learning from previous mistakes.

Furthermore, lean is not about headcount reductions; it is about being able to do more with existing resources. The concept often means the same things can be achieved using fewer people, thus human and other resources can be redeployed to create even more value. Hence, the purpose of lean thinking is to enable delivery of better healthcare at lower overall cost, rather than making staff redundant. Specifically, it provides the following benefits (Jones & Mitchell 2006):

Improved quality and safety – fewer mistakes, accidents and errors, will result and better quality good and services will be produced.

Improved delivery – The work gets done faster.

Improved throughput – The same people, using the same equipment, find they are capable of achieving much more results.

Accelerating momentum – A stable working environment with clear, standardised procedures creates the foundations for constant improvement.

From a perspective of manufacturing, lean thinking is a strategy to achieve competitiveness through identification and elimination of wasteful steps in products, services, or processes (Shinohara 2006; Womack & Jones 1996). It aims to substantially smooth the flow and drastically reduce waste and process variations (Reichhart 2007; Shinohara 2006; Taj & Berro 2006; Womack & Jones 1996). Waste is defined as the activity or activities that a customer would not want to pay for, and that do not add value to the product or service from the customer's perspective (Shinohara 2006). Once waste has been identified in the current or existing state, a plan is formulated to eliminate this to attain a desired future state in as effective and efficient a manner as possible. These activities belong to one of three sets of operations (Moden 1993):

- Non-value added activities
- Necessary, but non-value added activities
- Value-added activities

Similarly, in a healthcare service organisation, wasted time leads to high cost and affects the quality of patient care, thus it should be reduced. To achieve the leanness target, the activities that add no value, or that adversely affect the smooth flow of the process, are considered for elimination. Although some management professionals argue that lean manufacturing does not translate well to service industries, Bowen and Youngdahl (1998) show how it does apply to healthcare by providing theory, case studies, and context for lean applications. Flinders Medical Centre, a medium-sized public sector teaching hospital in Adelaide, South Australia, has, for some time, been implementing lean strategies (King, Ben-Tovim & Bassham 2006a) and has been able to operate below its budgeted costs (Jones & Mitchell 2006). Many applications of lean in healthcare have been published in academic journals and other media (see Table 2.3).

Table 2.3: Summary of Lean thinking literature

Author	Title	Domain	Key Area of Study	Findings/conclusion
Ben-Tovim et al. (2006) Australia	Redesigning emergency department patient flows: Application of Lean Thinking to health care	Emergency Department	• Lean Thinking • Patient flow • Process redesign	The streaming of patients into groups of patients cared in the ED improved patient flow, thereby decreasing potential for overcrowding.
Ben-Tovim (2007) Australia	Seeing the picture through" lean thinking"	Clinical Epidemiolog y	• Lean thinking • Patient flow • Process redesign	Error in execution of a process is an absolute waste.
Ben-Tovim et al. (2008) Australia	Redesigning care at the Flinders Medical Centre: clinical process redesign using" lean thinking"	Clinical process throughout the hospital	• Lean Thinking • Patient flow • Process redesign	The Redesigning Care program has enabled the hospital to provide safer and more accessible care during a period of growth in demand.
Dickson et al., (2008) USA	Application of Lean Manufacturing Techniques in the Emergency Department	Emergency Department	• Lean Thinking • Patient flow • Process redesign	Lean improved the value of the care.
Maier-Speredelozzi et al. USA	Applying Lean Principles to a Continuing Care Patient Discharge Process	Discharge Process	• Lean Thinking • Time-motion study	The greatest benefits are derived through identifying and eliminating wastes in the process
Jimmerson, Weber and Sobek, (2005) USA	Reducing waste and errors: Piloting Lean Principles at IHC	Intensive care unit Medical ICU Medical/surg ical unit Emergency department.	• Lean Thinking • Time-motion study	Discovered ample opportunity to improve efficiency and quality in health care by eliminating waste.
Miller (2005) USA	Going Lean in Health Care	Throughout the entire process	• Lean Thinking	Demonstrated that lean management can reduce waste in health care with results comparable to other industries.
Johnson et al. (n.d) USA	Attacking waste and variation hospital-wide: a comprehensive lean sigma deployment	Surgery	• Six Sigma • Lean thinking	The hospital has realized both a financial and cultural return on investment.
Rogers, Silvester & Copeland (2004) UK	NHS Modernisation Agency's way to improve health care	Across entire organisations	• Six Sigma • Lean thinking • Theory of constraints	The idea of lean thinking can suit health care organisations
Womack and Jones (2003) USA	Lean Thinking: Banish Waste and Create Wealth in Your Corporation	Medical system	• Lean thinking	Having multi-skilled teams taking care of the patient and an active involvement of the patient in the process is emphasized.

Author	Title	Domain	Key Area of Study	Findings/conclusion
Young et al. (2004) UK	Using industrial processes to improve patient care	Diabetic retinopathy	• Six Sigma • Lean thinking • Theory of constraints	Patients focused; Coordinate and balance activities; Identify those that constitute weak links or bottlenecks, and take appropriate remedial action.
Young et al. (2008) UK	A critical look at Lean Thinking in healthcare	Medical system	• Lean thinking	There is scope for methodological development, perhaps by defining three themes associated with value—the operational, the clinical and the experiential.
Den Boer et al. (1999) Netherlands	Preoperative time-motion analysis of diagnostic laparoscopy with laparoscopic ultrasonography	Preoperative Surgical process	• Time-motion study • Lean Thinking	This time-motion study provided detailed insight into the preoperative process of operation, leading to improvements in the surgical process and instruments used.

2.4 The approach of leaning thinking in healthcare

The strategies of lean thinking are applicable to health care (Balle & Regnier 2007; Jones & Mitchell 2006; Young et al. 2004). 'An obvious application [of lean thinking] to healthcare lies in minimising or eliminating (within the framework of clinical excellence) delay, repeated encounters, errors, and inappropriate procedures'(Young et al. 2004 p, 162). Hospitals may apply lean thinking to provide better services to their patients, especially in the operating theatre. One of the key principles of lean thinking is respect for the customer. In a healthcare setting the focus of service becomes the patient as compared to the customer in other settings.

The patient is the primary customer to the health care services since the patient justifies the existence of such services. However, this is sometimes hard to accept, especially in public healthcare where the patient does not pay directly for the services. Other customers to healthcare could be the patient's family, society in general as the major funding party, referrers as internal customers, and medical students. This indicates that there are many different customer groups to healthcare services. Hence, depending on the perspective, the definition of value will differ. However, because the main mission of healthcare is to treat and cure patients who are the end-consumers in the care process, it is argued that the patient should define what creates value in healthcare (Young et al. 2004). Womack and Jones (2003) advocate the application of lean thinking in medical systems. They argue that the first step in implementing lean thinking in medical care is to put the patient in the foreground and include time and comfort as key performance measures of the system. Having multi-skilled teams taking care of the patient and an active involvement of the patient in the process is emphasized.

Lean thinking has also been advocated in the healthcare setting of the USA through the use of the Six Sigma methodology, which in many ways resembles lean production techniques (Dahlgaard & Dahlgaard 2006; Tolga Taner, Sezen & Antony 2007; Young et al. 2004). Johnson et al. (n.d.) argue that Six Sigma and lean thinking are complementary, rather than competitive. The authors explain that both are business improvement methodologies, more specifically business process improvement methodologies. Their end goals are similar (i.e. better process performance), but they focus on different elements of a process. While Six Sigma is a systematic methodology to focus on the key factors that drive the performance of a process, set at the best levels, and held there for all time, lean thinking is a systematic methodology to reduce complexity and streamline a process by identifying and eliminating sources of waste in the process. Therefore, lean concerns what should not be done and aims to remove it; whereas, Six Sigma looks at what we should be doing and aims to get it right first time.

Other related literature also reveals that the implementation of lean thinking brings benefit to healthcare (Ahluwalia & Offredy 2005; De Koning et al. 2006; Jimmerson, Weber & Sobek 2005; Jones & Mitchell 2006; King, Ben-Tovim & Bassham 2006b). The following section discusses the theoretical perspectives that could be employed along with lean thinking in the identification of non-value added activities.

2.5 Theoretical perspectives

Coordination theory and socio-technical systems theory seem to have the potential to provide insights into the identification of non-value added activities in OTPM. Coordination theory (Crowston 1997; Malone, Thomas 1988; Malone, Thomas & Crowston 1990, 1994) serves as a way of managing interdependencies; whereas, STS theory helps understand OTMP because OTPM encompasses technical, as well as social, components. The combined perspectives are then applied within the lean thinking strategy to enable identification of each activity as VA or NVA. The concepts and techniques of time and motion (Barnes 1980) discussed in section 2.2 is employed to analyse those activities and the work setting in OR. Coordination theory and socio-technical systems theory are discussed next.

2.6 Coordination theory

We define coordination theory as a body of principles about how activities can be coordinated, that is, about how actors can work together harmoniously. It is important to realize that there is not yet a coherent body of theory in this domain (Malone, Thomas & Crowston 1990). The notion of coordination becomes relevant when one considers systems wherein interdependencies exist (Malone, Thomas 1988; Malone, Thomas & Crowston 1994). Taking the supply chain as an example, Skipper and Craighead (2008) developed propositions for technology–enabled coordination strategies for managing interdependencies. Thomson (1967) and Skipper and Craighead (2008) indicate the following three forms of interdependence in systems:

1) **Pooled interdependence:** This form of interdependence is the weakest form of interdependence which occurs when system components contribute to the whole with little direct relationships among themselves. Thomson (1967) and Skipper and Craighead (2008) suggest coordination by standardisation as a best strategy to cope in case of pooled interdependence.

2) **Sequential interdependence:** This form of interdependence occurs when each part of a system makes a discrete contribution to the whole and supports the whole. It occurs when there is ordered relationship of a serial type. The parts are arranged in a serial fashion with a direct interdependence in which an order aspect is involved. Thus, an activity cannot begin unless the activities that precede it are complete. In this type of interdependence, the activities of individuals depend upon the completion of jobs by others. Thomson (1967) and Skipper and Craighead (2008) suggest coordination by better communication as a best strategy to cope in case of pooled interdependence.

3) **Reciprocal interdependence**: involves input/output exchange in both directions. The author suggests coordination by mutual adjustment as a best strategy to cope in case of pooled interdependence.

Therefore, the need for coordination arises when there is some form of interdependency among activities or parts in an inter- or intra-organizational setting. In the words of Malone and Crowston (1994) ‘coordination is managing dependencies’. Malone and Crowston (p.91) identify eight types of interdependencies: shared resources, task assignments, producer/consumer relationships, prerequisite constraints, transfer, usability, design for manufacturability and task/subtask.

Coordination theory provides part of the theoretical perspectives to the present study as it provides a way to study activities in the operating theatre and the elements within each activity (Crowston 1997). It offers a framework for understanding and characterizing different types of interdependencies and identifies the activities that can be used to manage these interdependencies. The aim of this theory, therefore, is to define and identify activities and elements, as well as attempt to improve performance. Thus, it enables identification of potential areas where coordination problems are bound to arise: these are the areas where there are dependencies that constrain how tasks can be performed (Crowston 1997).

Coordination as a way of managing interdependencies could arguably be effective if the nature of a system and its components, as well as its environment, are clearly understood. Socio-technical system theory helps the understanding of systems as composed of a social and technical component and advocates the study of systems in the whole context of their external environment. Thus, CT is combined with STS theory to enhance the understanding of healthcare systems.

2.7 Socio-technical system theory

Socio technical system theory is a popular theory employed in work design in a setting where there are technology supported, self managed work groups. The STS theory enables examination of organizational systems from both the technical and social points of view (Geels 2004; Manz & Stewart 1997; Pasmore 1982). That is, STS theory is a systems-based approach for process analysis and redesign that considers an organization as a work unit composed of social and technical parts. The technical system is comprised of structures, tools and knowledge necessary to perform the work which produces products. The social system consists of attitudes and beliefs, contracts between employers and employees, reaction to work arrangements and the relationships between individuals and among groups (Appelbaum 1997; Geels 2004; Manz & Stewart 1997; Pasmore 1982).

These two components must work together to bring about a desired result, which could be a physical product or a psychological outcome. The key concept in the theory is the design of a system such that the two components would be optimally combined to yield positive outcomes; this notion is referred to as joint optimization (Kelly 1978; Manz & Stewart 1997; Pasmore 1982). In addition to joint optimization, STS theory also advocates the need for protecting the system from disruptions and disturbances from external system interventions and facilitating exchange of resources and information with external systems (Appelbaum 1997).

In relation to the present study, this theory is employed to identify and analyse the activities in the OTMP, which involves a combination of social and technical elements. Kelly (1978) and Pasmore (1982) indicated that prior studies focused mainly on the technical rather than the social aspects of activities in the operating room. In a recent study, Al-Hakim (2006) focused on the social aspect of the operating room. Similarly, social aspects of OPTM will be an area of focus in the present study. As Appelbaum (1997) indicates, STS theory also focuses on the interdependencies between and among people, technology and environment. Therefore, this theory is consistent with coordination theory and thus the two theories are compatible when combined in a research framework.

Al-Hakim (2006) suggests four social factors which contribute to process variations in healthcare: object (patient) behaviour, operating theatre team effectiveness, surgery success and surgical time. Performance of the operating theatre team in the process is not easily measurable. This is because healthcare professionals differ in skills and expertise, thus, it is hard to measure their effectiveness in dealing with various complexities during operation processes. Also, in the operating theatre, where the level of complexity and variability of activities is high, it is not always possible to predict the degree of success of an operation. Heart transplantation for example, was rarely successful when first introduced, though improvements have been achieved through time (Arena et al. 2007).

Further, it is not possible to fix an operation time for surgery as each operation is unique. The resultant unpredictability of surgical time renders difficult any attempt at precise scheduling of theatre lists. Therefore, the STS theory is employed to capture the social aspects within the operating theatre. As a result of these unique features of the operating theatre management process, the need for adapting lean thinking becomes evident.

2.8 Necessity for adapting lean thinking

Hospital and manufacturing production systems vary in a number of dimensions. There are several reasons for the notion that the concept of lean thinking should be adapted to fit the hospital system (Woodward-Hagg et al. 2007). From the STS point of view, major areas of difference include: necessity of human involvement, level of product uniformity, cycle time, waiting time, object behaviour, ease of performance measurement and process effectiveness (Al-Hakim 2006).

Advanced machinery could be designed and then skilled labour involvement could be minimized in a manufacturing setting; whereas, in healthcare, involvement of skilled professionals is necessary. In manufacturing, performance of workers in the production process is easier to measure. In contrast, performance of professionals in the process is not easily measurable. Again, this is because healthcare professionals differ in skills and expertise, and it is hard to measure their effectiveness in dealing with various complexities during operation processes. Also, products have defined characteristics in manufacturing; however, in healthcare, since the level of complexity and variability of activities is high, it is not always possible to predict the degree of the success of an operation (Al-Hakim 2006).

In addition, while products are uniform in manufacturing, every patient may require a different service in healthcare. For example, a single production process could be used to produce thousands of identical products in manufacturing. However, in healthcare, even health problems that appear to be similar could require a unique treatment. As a result, the designed process needs to be modified to fit the circumstances of each particular patient. Also, unlike manufacturing products which have defined characteristics, patients' behaviour is not predictable and could vary substantially. The patient is considered as a product; and service provided to the patient is highly dependent on the status of patient. Al-Hakim (2006) stated that significant disruption, for example the cancellation of surgery by a patient, could result from patient behaviour.

Further, production cycle time could be precise in a production setting, but it is not possible to fix an operation time in healthcare as each service is unique. Also, zero waiting time could be targeted in a manufacturing environment, whereas waiting time is not always a waste in healthcare. Sometimes it can even be considered as a value-added activity. If an operating theatre of the hospital is taken as an example, an anaesthetist does the job mainly at the beginning of the operation, while the other surgical team is involved in monitoring activities. In contrast, in a production line of manufacturing, if a worker is waiting or monitoring a process, it is considered as a waste that should be eliminated to improve efficiency (see Table 2.4 for summary of differences). These differences in setting between manufacturing and healthcare necessitate adapting the concept of lean thinking.

Table 2.4: Summary of the differences between the two settings

Organization type / Differences	Lean Thinking in Manufacturing	Lean Thinking in Healthcare
Necessity of human involvement	Automation is a major role to reduce human involvement, it reduces the need for high skill and knowledge	Skill, knowledge, and experience of professionals play major role
Ease of performance measurement	Performance of workers in the production process is easy to measure	Performance of professionals in the process is not easily measurable
Process effectiveness	Process outcome is predictable	It is hard to predict the degree of the success of healthcare service
Product uniformity	Machine produces identical products	Every patient require different service
Object behaviour	Products have defined characteristics.	Patients behaviour are not predictable and could vary
Cycle time	Cycle time of the production could be precise and determined in advance	Healthcare service cycle time could vary and difficult to determine prior to the service
Non-added value activity time	All type of inspection is waste and should be reduced or eliminated	In healthcare environment, monitoring and testing are essential
Information flow	Mainly depends on process flow	Healthcare activities are information based activities.

Lean thinking provides a broad context to apply the techniques of time and motion study and coordination theory. Time and motion study is primarily concerned with improving efficiency of activities; its use in a lean thinking context makes it more meaningful by focusing on elimination of non-value adding activities. The concepts in coordination theory could also fit well in a lean thinking approach because coordination is an approach of fostering efficiency.

2.9 Gap in the literature

There is an abundance of studies in healthcare under the concept of lean thinking, time and motion study, coordination theory and Socio-Technical System theory. However, these studies considered each concept and theory separately, or did not combine these theories and concepts in a comprehensive fashion in a single investigation. Given the increasing need for minimising NVA activities in healthcare, such an integrated approach could provide additional insights into elimination of NVA activities in this sector. Thus, the present study attempts to fill this gap in the literature by considering all of these concepts and theories in a comprehensive conceptual framework. In addition, the literature review indicates that the cause of delay and disruption inside ORs are usually just reported, however, prior studies did not focus on the root problem or causes of non-value added activities and delays inside ORs. Furthermore, prior studies did not examine inefficiencies within the value added activities; that is, the focus has been on delays and disruptions. In conclusion, this research considers the following gaps:

(1) The lack of an integrated comprehensive conceptual framework.
(2) The lack of studies focusing on the root causes of delays and disruption within the ORs.
(3) The lack of studies that examine value adding activities to identify inefficiencies.

2.10 Summary

The existing literature suggests wasted time in healthcare is increasing the costs to institutions, as well as affecting the quality of patient care. Some institutions in the healthcare industry have recognised the need for eliminating disruptions and delay in a bid to provide quality professional services at reasonable costs. To continuously reduce the high levels of NVA activities, the OTMP needs to be broken down into its components and the interdependencies among systems grasped. Activities, and the workplace setting in which they are carried out, could be studied using a time and motion study. Within a combined framework of STS theory and coordination theory, a time and motion study could be applied to identify NVA activities in ORs. Lean thinking adapted to a healthcare setting could serve as an integrating mechanism to propose ways of minimising NVA activities. To this end, the following chapter provides a detailed research design to address the question: *How can non-value added activities be identified and reduced using adapted lean thinking within the operating theatre management process (OTMP)?*

CHAPTER 3 - RESEARCH DESIGN AND METHODOLOGY

The literature review in the previous chapter has highlighted the necessity of adapting lean thinking to a healthcare setting. As the healthcare environment has both social and technical dimensions, there needs to be a theoretical framework that takes into account both these aspects when adapting lean thinking to a healthcare environment. This chapter develops a conceptual framework for the study using socio-technical theory and coordination theory. The chapter then describes and explains the research methodology in terms of the case study method employed in data collection, analysis and interpretation. Also described are the precautions that have been taken to minimize possible validity threats.

3.1 Conceptual framework

A healthcare setting combines both social and technical aspects. It also involves teamwork where groups of professionals are engaged at different steps to execute a surgery. This makes coordination among and within groups vital for the successful operation of tasks in a healthcare setting. In view of this notion, the present study employs adapted lean thinking in a research framework that draws on Socio-technical System (STS) theory and Coordination Theory (CT). STS Theory has been employed to explain how OTMP can be considered as a socio-technical system in which each activity within the process has both technical and social elements. CT was then employed to provide insights into the complex interdependencies between activities, as well as the interdependencies between the elements of an activity itself. The concept of lean thinking, adapted to a health care setting, has been employed to identify ways of reducing non-value adding activities and, thus, waste in terms of delay and disruption. Figure 3.1 presents a conceptual framework of the study.

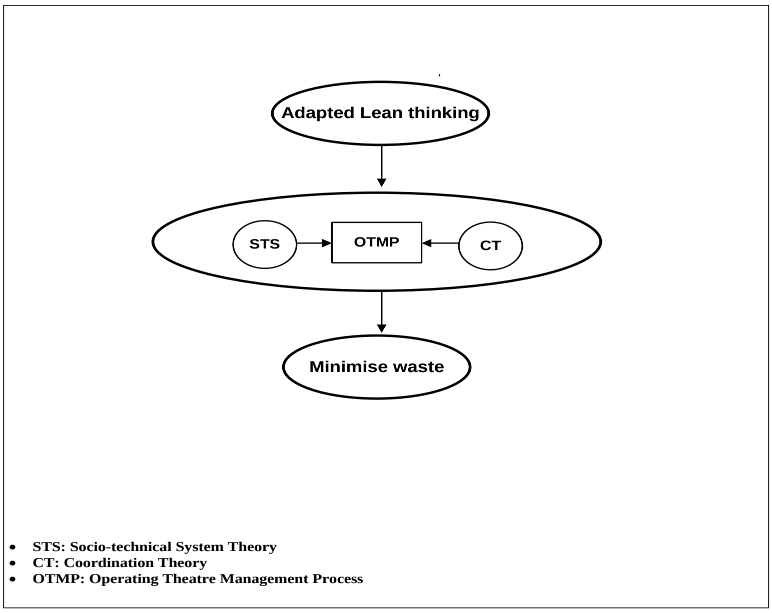
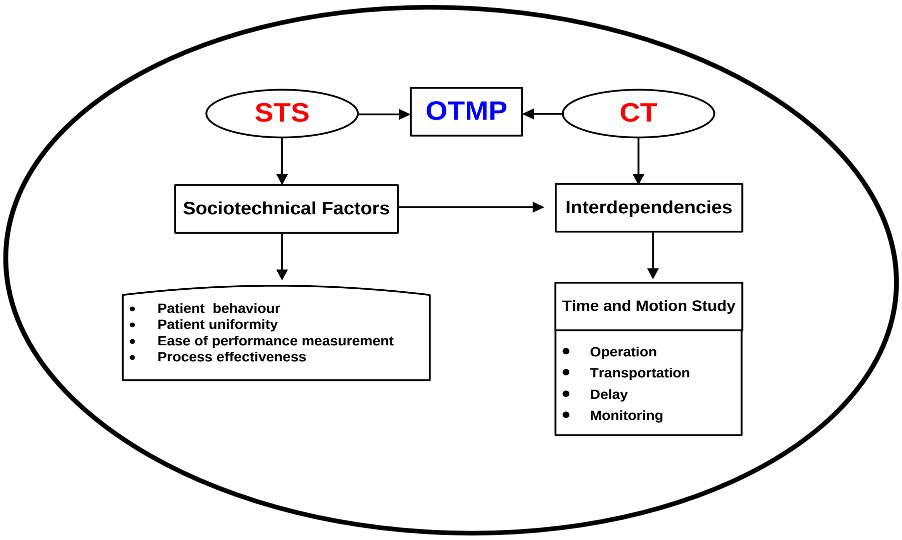


Figure 3.1: The Theoretical Framework

STS theory and coordination theory have a detailed set of dimensions. STS theory caters for four socio-technical factors: patient behaviour, patient uniformity, ease of performance measurement, and process effectiveness. Coordination theory indicates interdependencies that exist among and within processes/activities. This theory is informed by time and motion study which provides the tools for the study of operations, transportation, delay and monitoring. Figure 3.2 depicts STS theory and coordination theory.



- STS: Socio-technical System Theory
- CT: Coordination Theory
- OTMP: Operating Theatre Management Process

Figure 3.2: The Relationship between STS and CT

This study focused on the identification of non-value added activities in an OT system. Therefore, it considered the nature of work processes and the time taken to accomplish each task in a process. This calls for the use of the components of the time and motion study, which is a systematic study of work systems with the purposes of developing an allowed time standard to perform a given task based upon measurement of work content of the prescribed method with due allowance for fatigue and unavoidable delays. It further entails analysing the various body motions employed in performing a task for the purpose of eliminating ineffective movements and speeding effective movements (Barnes 1949; Kettinger, Teng & Guha 1997).

3.2 Research design

This study was basically conducted as an action research with an aim of solving real world problems. As a result, examination of issues in a real world context was necessary to conduct the study. Thus, the study was informed by an exploratory qualitative case study. A public hospital was chosen for the study, where 22 surgeries were observed. Moreover, additional information was collected as necessary through personal communications with medical staff (surgeons, scrub nurses, technicians etc.) and review of documents. This section describes the research methods adopted in terms of the data collection procedures and methods of analysis.

3.2.1 Selection of case study methodology

This study focused on solving real-world problems with particular attention on minimizing waste in surgery activities. A qualitative case study is an analysis of a situation, described by prose and literary technique, as opposed to quantitative techniques where measurements are involved (Wilson 1979). Yin (2003) defines case study research method as 'an empirical inquiry that investigates a contemporary phenomenon within its real-life context'. Yin (2003) also points out that the use of the case study method is appropriate when the boundaries between phenomenon and context are not clearly evident and that the use of this method enables the use of multiple sources of evidence. A case study emphasizes detailed contextual analysis of a limited number of events or conditions and their relationships. One of the strengths of case study research is that it provides rich data because the object of the case is studied in its normal setting, or context. According to Yin (2003), the case study is used to answer how and why questions; it is also useful when there is no control over the situation or behaviour of the individual to be studied. As surgery activities are socio-technical systems that involve various forms of interdependencies, the use of the case study method enabled the capturing of data in the real contexts of operations. Hence, this study was conducted as an exploratory study using a qualitative approach.

In the case study method, a single case or multiple cases could be a subject of study. A single case may be chosen for a study for an unusual circumstance, or if it is of interest by itself (Miller & Salkind 2002). A multiple case study involves the use of two or more cases for examination. Multiple case studies are often used in research to solve a particular problem or issue. In this study, Toowoomba Heath Service (THS) was used as a case study in which 22 surgery cases were studied. The use of a single hospital is not expected to undermine the usefulness of the results because there is considerable similarity in the way hospitals in Queensland (Australia) operate (Foo, 2006). Before the data collection commenced, the researcher undertook training at Princess Alexandra Hospital (PAH), Brisbane, Queensland, Australia. This training was carried out in conjunction with the researcher's supervisor who has been undertaking a related study. The supervisor's presence helped the researcher familiarise herself with the operating theatre setting and the activities.

3.2.1 Observation protocol and interview protocol

The researcher was allowed contact with respondents from Toowoomba Health Service (THS) after permission had been granted by Queensland Health and the Toowoomba Health Service District Human Research Ethics Committee. This permission enabled the team (consisting of a Masters Degree student, and the supervisor) to work closely with Liaison Officers assigned by the hospital. The initial contact with respondents was via a face-to-face meeting, with further meetings arranged via e-mail or telephone.

To ensure confidentiality, a Commencement Form was signed to declare that all investigations carried out for this research were in accordance with the “Declaration of Helsinki 2000” and with the latest statement by the National Health and Medical Research Council on Human Experiments and on Scientific Practices. The research was also conducted on the condition that there was no access to identifiable patient information and no direct contact with patients or staff other than those specified.

This research employed the following steps as part of the observation protocol:

1. The liaison officer of the hospital was contacted in advance to obtain a schedule of the surgeries that would be considered suitable for observation and to generate data for the study.
2. The liaison officers chose the days in each week to undertake the observation. The researcher observed the activities, along with the supervisor and liaison officers, thus allowing the researcher to ask questions for clarification during and after the observation.
3. On the day of observation, the researcher arrived early enough to be able to change clothing because the observation takes place in a sterile area of the operating theatre suite. In the preoperative department, the liaison officer introduced the researcher to patients and staff and explained to them that the researcher was observing the process and not the person, and that all information would be strictly confidential with no identification of the names of individuals.
4. The liaison officer routinely obtains the composition of the team involved in the operation before the commencement of surgery. The researcher recorded those term members’ details into the observation sheet obtained from liaison officer. In addition, the work area was also sketched before the start of each operation by the liaison officer.
5. The research team followed patient progress from the pre-operative holding area through to discharge. The researcher observed and recorded the timing of all location changes and all the activities inside the OR. As much detail as possible was observed and recorded to capture sufficient details to allow identification of problems.
6. After observation of each surgery case, the researcher and her supervisor arranged meetings with the liaison officer, surgeons and nurses for the purpose of reviewing, revising and recording the major non-value added activities and causes.

Monthly meetings were conducted with the liaison officer and other related professionals, including surgeon and nurses. The research employed the flowing steps as part of the interview protocol:

1. The first interview was conducted with everyone involved in the project, as stated by the hospital, to obtain initial information necessary to understand how the OTMP breaks down its sub-process and activities for the purpose of data collection.
2. Subsequent interviews followed an iterative pattern. The first part of the interview was used to review and revise the major non-value added activities and causes, and then recorded by the researcher—together with information collected from the previous observed surgery cases. Next, certain activities were highlighted for further analysis and examination with the coordinator and people from the specific specialty relating to the chosen topic of the interview. After each interview a new surgery case was observed and recorded by combining ideas and experience from the previous surgery case.
3. Location of interview: the interviews took place in an allocated room in the hospital itself.
4. Limiting self-bias to limit self-bias: the first step was to have a firm grasp of the issues being studied. This allowed for the proper asking of questions and interpretation of answers. The research team strived to be adaptive and flexible, and to see newly-encountered situations as opportunities—not threats. To prevent bias, a researcher should avoid preconceived notions, including those derived from theory and to be responsive to contradictory evidence (Yin 2003).
5. Thanking respondents: the respondents were thanked very gratefully at the end of each and every interview for their willingness to help and contribute to the data collection.

3.2.2 Data collection and analysis using Adapted Lean Thinking

A key strength of the case study method involves using multiple sources and techniques in the data gathering process (Yin 2003). The researcher determines in advance what evidence to gather and what analysis techniques to employ with the data to answer research questions. Data gathered are normally largely qualitative, although it may also be quantitative. Yin (2003) indicated that there are six major tools to collect data which can include archival records, interviews, documentation review, direct observations, participant observations and even the collection of physical artefacts. In this case, archival records, interviews, documentation review, and direct observations were employed during the data collection.

Over a five months period from August through December 2008, a total of 22 surgeries were observed in THS. Each observation was recorded in a standardised sheet shown in Appendix 2. An observation sheet similar to that employed by Wallace and Savitz (2008) and Al-Hakim (2008) has been used in this study because it has been validated. It is designed to observe activities of work in progress with a view to identifying non-value added activities. The sheet from Wallace and Savitz (2008) contains columns for recording start up times, description of activities, operation, clarifying, error/defect, processing, motion, other, break, interruption and location change, and problems. Conversely, in a recent study by Al-Hakim (2008), the observation sheet contains columns only for recording start up times, the staff member involved in the operating theatre, and a description of activities. It also employs four standardized symbols from time and motion study for all elements of an activity (□= monitoring, O= operation, D = delay, → = transport).

Transportation occurs when an object is moved from one place to another, except when the movement is an integral part of an operation or an inspection. It occurs when there is any change in location of an object. Then, a delay occurs when the immediate performance of the next planned action does not take place. An operation occurs when an object is intentionally changed in one or more of its characteristics. An operation represents a major step in the process and usually occurs at a machine or workstation. In this study, operations are considered as all activities that change the clinical information. On the other hand, delay was taken as NVA activities. It may be caused by patient behaviour, surgeon effectiveness, resources shortage, or information error. Monitoring may be essential, but adds no value if it does not change the clinical information.

Furthermore, this study used Al-Hakim's (2008) observation flow sheet, and by actually observing a person performing the job sequence. Benbasat, Goldstein and Mead (1987) believe that systematic organization of the data is necessary to prevent the researcher from becoming overwhelmed by the amount of data and to prevent the researcher from losing sight of the original research purpose and questions. A case study database has been built and maintained to contain data and evidentiary information.

3.2.3 Data collection procedures

Direct observation by the researcher was undertaken to map the time spent in various types of activities within the operating theatre. In this sheet, only the activities and the time spent within the OR were recorded.

The researcher recorded the composition of the operating team member involved in the surgery (obtained from the liaison officer) before the operation started. A typical operation may involve surgeon, assistant surgeon, anaesthetist, assistant anaesthetist, technician, scrub nurse, and two scout nurses, as well as the patient. Once the operations started, the researcher recorded the commencement time of the operations in hours and minutes at the top of each flow sheet and began recording at row 1 on the flow sheet. Records were made of every staff member's activities during each minute interval by the relevant symbols (□= monitoring, O= operation, D = delay, → = transport), along with a brief explanation of major activities in the description columns. As much detail as possible was taken to capture sufficient details to allow identification of problems (Table 3.1).

Table 3.1: Sample of observation sheet

Start Time 9 : 00	Surgeon	Anaesthetist	Technician	Scrub nurse	Scout nurse	Wards man	*Description*
Minute			→			→	Technician & wardsman transport the patient into the OR
1			**O**			**O**	Wardsman along with technician moved patient to the bed which is inside the OR
2	□	**O**	**O**	**O**	**O**	**O**	Anaesthetist administers the oxygen to patient; surgeon monitoring; the rest of OR term member assist anaesthetist
.							
.							
35	**D**	□		**O**	□	**O**	Something wrong with the equipment, asking for help from scrub nurse and wardsman
.							
.							
55	□	**O**	**O**	**O**	**O**	→	Wardsman moves patient to recovery; the rest of team members clean up the OR, and prepare for the next surgery

All location changes and interruptions were noted with a hatch mark during each minute interval. At the end of each observation, data were entered into a data file and the summary reviewed. The data were saved in the data file before the data were entered. For each minute interval, the fraction of time spent in each activity category was entered on the data worksheet. For example, if 30 seconds is spent travelling and 30 seconds is spent in operations, 0.5 would be recorded in the appropriate row and column intersection. When the researcher was not sure, she estimated the fraction of the minute spent in the activity. For each minute interval, the frequency of interruptions and location changes were entered. In addition, notes were recorded in the Activity Description column. The data were saved, along with a separate backup copy, after each data entry. For each observation a narrative summary, including any notable features of the observed surgery and details of observed errors, was recorded.

3.2.4 Data analysis

Non value added activities are generally defined as an “undesirable gap between an ideal and actual state that hinders a worker’s ability to complete his or her tasks, impacts service quality or patient satisfaction” (Tucker 2004). As mentioned above, staff activities are recorded on a flow sheet divided into one-minute intervals (timed with a stopwatch). At the end of the observation period, the researcher discussed with the surgeon and/or the other team members as necessary to obtain clarification. Upon completing the data collection, the researcher summarized the data into an Excel data spreadsheet and reviewed the observed surgeries.

Symbols were used to make the data analysis manageable. Tables 3.2(a) and (b) summarise the symbols and what they stand for. As indicated in Table 3.2(a),⓪,①,②,③ and ④ are all value added activities from the hospital’s point of view. However, this study considers that some factors, such as inadequate patient positioning, prevented the surgeon from comfortably observing the anatomy area when performing this surgery, resulting in some delays and disruptions. This kind of factor is not related to a surgeon's technical experience, but there are some sort of hidden delays associated with this operation. Therefore, the symbols in Table 3.2(a) stand for different classes of value added activities, depending on the proportion of the delay that is considered non-value adding. The suggested reductions in time were decided after discussions with the operating theatre members involved in the activities. The symbol ⓪ stands for the fully value added activities, the time for which cannot be reduced. For some activities, although the activities were necessary, some interruptions, wasted motion, or inefficiencies of other sorts were involved. Thus, ①,②,③ and ④ stand for the activities in which delay or inefficiencies was observed. This study considers the delay in the above activities equivalent to 20 percent, 40 percent 60 percent and 80 percent of the total activity durations respectively.

Table 3.2(a): Summary of symbols used to identify activities

Activity classification	%Non-value added activities	Symbol description
⓪	0%	fully value added activities
①	20%	time could be reduced by 20%
②	40%	time could be reduced by 40%
③	60%	time could be reduced by 60%
④	80%	time could be reduced by 80%

On the other hand, Table 3.2(b) summarises the different types of delay, along with the symbols used. Some of the delays were necessary; for instance, although monitoring a patient from the pre-operative area to the operating room takes time, it is a necessary activity. This movement is a non-value added activity; yet it is necessary. However, some non-value added activities can be considered as totally wasted, while others may contain two parts: necessary delay and unnecessary delay. Similar to the value added activities, delay was classified into five categories in this study: starting from delay which is fully unnecessary (D_0) to delay which comprises 20 percent of necessary delay (D_4) as shown in Table 3.2(b). The delays were recorded with a 12 second interval. Thus, D_0, D_1, D_2, D_3 and D_4 stand for full minutes, 48 second, 36 seconds, 24 seconds and 12 seconds delay. Accordingly, the delays were converted into minutes using conversion factors as indicated in the third column of the table.

Table 3.2(b): Summary of symbols used to identify activities

Type of delay	Duration in seconds	Conversion factor to minutes	Symbol description
$\mathbf{D_0}$	1 minute	100%	Non-value added activities in minutes
$\mathbf{D_1}$	48 second	80%	Non-value added activities in 48 seconds duration
$\mathbf{D_2}$	36 second	60%	Non-value added activities in 36 seconds duration
$\mathbf{D_3}$	24 second	40%	Non-value added activities in 24 seconds duration
$\mathbf{D_4}$	12 second	20%	Non-value added activities in 12 seconds duration

3.2.5 Validity considerations

In this study, Toowoomba Heath Service (THS) has been selected for the case study and Princess Alexandra Hospital (PAH) has been selected for training of the researcher. As in all case studies, generalizability of the findings to a population is not sought, that is, external validity—the extent to which a study's results apply to situations beyond the study itself (Graziano & Raulin 2007). Nonetheless, the findings of the study are expected to have relevance to other similar settings because the real case study setting is generally bound to apply in other health service organizations (Foo 2006). Therefore, being a single case study does not reduce the validity of the results.

3.3 Summary

In this chapter, the theoretical framework within which the study was undertaken has been discussed. A combination of two theories, i.e. STS theory and coordination theory were used to formulate the conceptual framework. STS theory was used to explain the social and technical aspects of the processes involved in healthcare activities. Coordination theory has been employed to discern the possible interdependencies among activities, components and work groups. In addition, time and motion study was used as a tool for analysis of processes. Lean thinking is also used to identify and reduce non-value adding activities. The detailed methods for data collection and analysis have also been provided in terms of the purpose of this research, the research design and the limitations of this research. The research design employed a qualitative case study method. Based of the methods described in this chapter, thorough analyses and discussions of the case studies are reported in the following chapter.

CHAPTER 4 – THE CASE STUDY

Based on the research methods described in the previous chapter, this chapter presents an analysis of the case study. Firstly, the chapter introduces a background of the organization used for observation of operating theatre activities. Section two presents the results and discussion of the case study, followed by the final section, section three, which provides a summary of the chapter.

4.1 Background of the hospital

This study was conducted on the operating theatre department of Toowoomba Health Service (THS), a public sector institution located in Toowoomba, Queensland. THS operates a 261-bed facility, composed of 164 acute beds, 57 mental health beds and 40 day beds. The hospital employs about 2000 staff and operates with 13 departments, namely, Surgical, Anaesthetic, Orthopaedic, Obstetric and Gynaecology, Paediatrics, Emergency, Critical Care, Medical Imaging, Medical, Renal, Public Health, Oncology, and Rehabilitation. There are four clusters in the hospital (see Appendix 1): surgical cluster, women's and children's health, clinical support; and medical. The surgical cluster includes four types of services: surgical, anaesthetic, orthopaedic and preoperative.

THS serves as a teaching hospital, as well as a major referral centre providing a comprehensive range of healthcare services to Toowoomba and the surrounding rural areas. It is the first regional centre to have a rural and remote healthcare focus. Additionally, the hospital provides general medical and nursing services in medicine, oncology/palliative care, as well as other services in nutrition, occupational therapy, physiotherapy, psychology, social work, speech pathology and podiatry. Furthermore, THS has a rural allied health team and an allied health locum service and it provides allied health services in nutrition, occupational therapy, physiotherapy, psychology, social work, speech pathology and podiatry.

The surgical department of THS is responsible for six operating theatres. Of these, four are used for elective lists that are run for two sessions per day: from 08:30 to 12:30; and from 13:00 to 16:30 hours. All patients scheduled for morning operations are required to arrive in the theatre admission department no later than 7:00 a.m. in order to complete the admission check in. Patients scheduled for afternoon operations are required to check into the admission department before 10:00 a.m. (Strong 2008, per. Comm., 29 September). The patient surgery lists are scheduled by a surgeon prior to the surgery day, with the schedule being dependent on the completion of the previous day's outcomes. The other two theatres are dedicated to 24 hour emergency surgery and to 24 hour caesarean section surgery. There are eight recovery wards catering to the theatre patients. Every surgeon has his/her own waiting list, and each specialty area has at least one clerk to manage the waiting lists.

THS provides surgery services to thousands of patients per year. For example, the hospital serviced 5,980 patients for the nine month period from July 2007 through to March 2008 (see Table 4.1).

Table 4.1: Surgery cases (July 2007 – March 2008)

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
Total	705	759	714	742	741	619	624	811	268	5,980
Elective surgery	366	353	388	382	413	316	250	397	131	2,996
Emergency surgery	261	306	225	270	266	218	290	290	98	2,224
Other surgery	79	99	101	90	62	85	83	124	37	760

Source: Adapted from Toowoomba Health Services' records

In recent years, the problem of the length of surgery waiting lists has increased to an alarming degree (AMA Queensland 2005). THS has a long waiting list for each theatre and it has attempted to document the obvious delays in operating theatres, and pinpoint their causes. From a conversation with a THS Operating Theatres Data Manager, Sylvia Johnson, it was revealed that the delay calculated by the THS was 63 hours and 52 hours in the years 2007 and 2008 respectively (Johnson 2008, per. Comm., 23 September) and continues at the current rate. Nonetheless, the reasons identified by THS for the delays were rather general in attempting to identify the root cause of delays within the operating theatre. This might suggest the need to closely examine the activities of the operating theatres to identify any delay resulting from inefficiencies. Foo and Al-Hakim (2008) identified a technique for mapping operating theatre management processes with a view to management waiting lists and Al-Hakim (2008) stressed the importance of information flow in the management of operating theatre processes.

Following on from the research of Foo (2008) and Al-Hakim (2008), the present study examines the operating theatre activities from the perspectives of time and motion study, coordination theory and socio-technical theories to bring into light some non value adding activities that could be minimized with the application of lean thinking. Thus, the study has been undertaken to examine the operating theatre management process using a combined theoretical framework to identify NVA activities and to minimise them by using lean thinking.

4.2 The case study

The data collection commenced after obtaining ethical clearance from Queensland Health as part of a large project titled 'Adapted lean thinking for healthcare service'. The National Ethics Application Form was revised four times before final approval was granted. Prior to the data collection, the researcher undertook training at Princess Alexandra Hospital (PAH), Brisbane, Queensland, Australia to help familiarise the researcher with the operating theatre setting and its activities.

The operating theatre suite (OTS) is located on the third floor of the Emma Webb Building. The pre-operative holding area is designed to accommodate the admission of patients to the OR. A registered nurse is allocated to this area on the morning shift from 7:30 a.m. to 4:00 p.m. The anaesthetic bay is the area within the OR where the patient is assessed and prepared for anaesthesia. The OTS has six functioning operating theatres. Theatres one, two, five and six are allocated to specific elective surgery and the rooms are equipped accordingly. Theatre three is a designated obstetric theatre. Theatre four is the designated emergency theatre. The recovery room is situated near the entrance of the OTS. There are eight bays commissioned within the unit. Post-operative patients are closely monitored until they are physiologically stable. Centrally located in the OTS, the sterile stock room is staffed by a registered nurse and an assistant in nursing. Reusable and disposable sterile supplies are stored in this area. A dumb waiter serves as the transport mode for sterile supplies between the central sterilising department and the sterile stock warehouse one floor below (level two) (see the operating theatre suite map in Appendix 2; Toowoomba Health Services 2008).

Over a five month period from August through to December 2008, a total of 22 cases were observed in the operating theatre of THS. Data were collected primarily through observation of operations in the case hospital. The data were recorded in an observation flow sheet. This sheet was chosen because its validity has been tested as it has been employed by Al-Hakim (2008) for a similar study; however, the sheet was modified to fit the purpose of this study. It is designed to observe activities of work in progress with a view to identifying non-value added activities. The adapted observation sheet contains columns only for recording start up times, the staff members involved in operating theatre, and a description of activities. The observation flow sheets for two surgery cases are provided in appendices 3 and 4.

Staff activities are recorded on a flow sheet divided into one-minute intervals (timed with a stopwatch). At the end of the observation period, the researcher discussed with the surgeon (and all the other team members if necessary) to obtain clarification. Upon completing the data collection, the researcher summarized the data in an Excel data spreadsheet and reviewed the observed cases.

4.2.1 Data collection procedures

The liaison officer of the THS was contacted in advance to obtain a schedule of the surgeries that would be considered suitable for observation to generate data for the study. Once the schedules were obtained, the liaison officers chose the days in each week to undertake the observation. The researcher observed the activities, along with the supervisor and liaison officers during the observations. On the observation date, the researcher arrived early enough so as to be able to change clothing because the observation is in a sterile area of the operating theatre suite. In the preoperative department, the liaison officer introduced the researcher to patients and staff and explained to them that the researcher was observing the process, not the person, and that all information would be strictly confidential with no identification of the names of individuals.

In the next step, the liaison officer obtained the composition of the team involved in the operation before the surgery started. The researcher recorded those team members into the observation sheet obtained from the liaison officer. In addition, the work area was also sketched by the liaison officer before the start of each operation.

The research team followed patients' progress from pre-operative holding area until discharge. The researcher observed and recorded the timing of all location changes and all the activities inside the OR. And the researcher recorded the commencement time of the operations in hours and minutes at the top of each flow sheet, and began recording (at row 1) on the flow sheet. The time spent on each activity was recorded in the appropriate activity column. A record was made of the activities of all staff during each minute interval by the use of relevant symbols and the activity description columns. As much detailed information as possible was taken to capture sufficient details to allow identification of problems. All location changes and interruptions were noted with a hatch mark during each minute interval. At the end of each observation, data were entered into an Excel data file and the summary reviewed. The data were saved in the data file before the data were entered. For each minute interval, the fraction of time spent in each activity category was entered on the data worksheet. For example, if a 30 second period is spent travelling and another 30 second period is spent in operations, 0.5 would be recorded in the appropriate row and column intersection. When the researcher was unsure, she estimated the fraction of the minute spent in the activity. For each minute interval, the frequency of interruptions and location changes were entered. In addition, notes were recorded in the Activity Description column. The data were saved, along with a separate backup copy after each data entry. For each observation a narrative summary, including any notable features of the observed case and details of observed errors, was recorded.

After completed observation of each surgery case, the researcher and supervisor managed discussion meetings with the liaison officer, surgeons and nurses for the purpose of reviewing and revising the major non-value added activities and causes recorded by researcher.

4.3 Data analysis

This section illustrates the data analysis procedures employed in the study using two surgery cases with large numbers of non-value added activities. This is followed by a summary of statistics of the 22 surgeries observed. Finally, the section summarizes non value-adding activities in all the 22 surgeries observed.

4.3.1 Analysis of data for two surgery cases

This section presents a detail description of two surgery cases. Records were made and the time calculated from the time the patient was moved to the operating room to the time the patient was moved out of the room, as illustrated in the observation flow sheet for surgery case A (see Appendix 3). The observation flow sheet shows the major activities with symbols and descriptions in the operating room.

Surgery Case A

General information about surgery case A is summarized as follows:

- Patient arrival time to pre-admission clinic: 6:45 am
- Patient arrival to pre-operative holding area: 8:23 am
- Patient arrival at anaesthetic bay: 9:28 am
- Patient moved to OR (operating room): 9:48 am
- OT session end and patient was out: 13:02 pm
- Total session time: 192 minutes

Table 4.2 presents a summary of the preventable delay observed in surgery case A. As indicated in Table 4.1, symbols⓪,①,②,③ and ④ stand for four types of activities as observed, with varying levels of inefficiency. The ⓪ symbol stands for activities that are fully value added and thus with 0 per cent reducible time. In ①, 20 percent of the time could be reduced; in ②, 40 percent could be reduced; in③, 60 percent could be reduced; and in ④, 80 percent could be reduced. On the other hand, D_0 to D_4 stand for delays, i.e. where there is no activity. The level of being preventable varies across the four types of delay. In D_0 delays are 100 percent preventable; in D_1 80 percent are considered preventable; in D_2 60 percent are considered preventable; in D_3 40 percent of the delay are considered preventable and in D_4 20 percent are considered preventable. Thus, the times indicated in column two are multiplied by the adjustment factors in column three to determine the total preventable delay indicated in column four. The most frequent reasons for delay and disruption identified in surgery case A was as follows (see details in observation sheet in Appendix 3):

- Surgeon's work being interrupted by student and assistant surgeon (assistant surgeon under practice).
- Patient's positioning is not adequate to surgeon and affected the surgeon's performance
- Surgeon performs surgery preparation without assistance from other surgical team.
- Shortage of staff to move patients to recovery bed.
- Scrub nurse doing the clean up alone without help from other related staff.

Table 4.2: Summary of preventable delay (surgery case A)

Activities	Units	Adjusting factor	Total preventable delay	Reasons
⓪	125	0%	0	
①	13	20%	2.6	- surgeon's work has been interrupted by student - assistant surgeon practice surgery - shortage of staff move patient to recovery bed
②	13	40%	2.6	- surgeon working without assistance - scrub nurse does the clean up alone
③	1	60%	0.6	- surgeon attempts to adjust light without help
④	1	80%	0.6	- surgeon working and talking to students at the same time
D_0	22	100%	22	- surgeon adjusting operating theatre table during the surgery - surgeon trains students - surgeon asks for suitable tools - surgeon asks for demand material - surgeon adjusting chair during the surgery - surgeon asks help for adjusting equipment
D_1	7	80%	5.6	- searching for tools - adjusting equipment - searching and bring suitable tools from outside - adjusting the positioning of patient's head - surgeon moves to different location - adjusting surgeon's chair
D_2	4	60%	2.4	- adjusting operating theatre table - training students - searching and bring required material
D_3	2	40%	0.8	- adjusting the positioning of patient's head - training assistant surgeon;
D_4	4	20%	0.8	- adjusting the positioning of patient's head - training student - adjusting equipment
Total	**192**		**38**	

% Preventable delay = 38/192= 19.79%

As indicated in the above table, there was a total session time of 192 minutes in surgery case A. Adjusting the delays into a preventable level indicates that 38 minutes could have been saved. The percentage of preventable delay, which is the total preventable time divided by total surgery time, was 19.79 percent of the total session time and was non-value adding in surgery case A. The reasons for the delays in each category of activity and each category of delay are diverse. Table 4.3 summaries the identified non-value added activities, and causes and effects of the non-value adding activities, as well as recommended action to prevent these delays. The recommended actions were forwarded from the perspectives of coordination theory and relevant principles of motion economy with a view to minimization of delay under the concept of lean thinking.

Table 4.3: Non-value added Activities analysis for surgery case A

Non-value added Activities	Cause	Effect	Required action
Surgeon searching for instruments	- Failure to have the correct instruments available for the surgical procedure	Delay	- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid the missing and unsuitable material, equipments, and instruments
Surgeon makes explanations to assistant about patient's health condition	- The explanation was not made in advance	Delay	- This type of communication should done before the start of the surgery through better coordination
Surgeon adjust operating theatre table height during the surgery	- Operating theatre table not adjusted at the proper height before the operation	Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section by updating surgeon preference sheet before the surgery
Surgeon prepares and drapes the patient without assistance	- Non attendance of OR staff including (nurses and wardsmen)	Delay	- Undertake better coordinated between OR staff
Surgeon asking for help regarding equipment	- Equipment not adjusted properly in advance	Delay	- Require better coordination between OR preparation team and surgeon by adjusting and testing equipment in advance
Surgeon trains students and explain activities to assistant surgeon	- Student asking questions	Delay	- Experienced assistant surgeon could help answer the questions or surgeon answer the questions to students while assistant surgeon do the surgery instead
Students and Anaesthetist keep talking during the surgery	- Personal	Disruption, Delay, Potential Error	- Require a protocol for students and theatre staff to read and understand before they attend to theatre
Surgeon re-adjusting the head of the patient many times	- Patient's positioning is not adequate - Unsuitable attachment	Disruption, Error Delay	- Updated surgeon preference sheet before the surgery
Surgeon asks for replacement instruments	- Failure to record completed specifications and confirm instruments in advance (in this case, needle should be longer than supposed to be)	Delay	- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid the missing and unsuitable material, equipments, and facilities. This requires better Coordinated between surgeon and nurses

Non-value added Activities	Cause	Effect	Required action
Nurse goes outside to bring back instruments	- The sterile stock room is long distance to operating room	Delay	- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid the missing and unsuitable material, equipments, and facilities during the surgical operating - Use coding system to record specification of material, equipments, and facilities
Surgeon adjust chair and table during surgery	- The table did not adjust properly and the chair is not comfortable	Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section in order to avoid re-adjustment of instruments. - Provide a chair of the type and height to permit good posture by apply motion principle 4,6,8,9, 17
Surgeon moves around operating theatre table	- Positioning of the patient prevent surgeon to comfortably observe the anatomy area	Disruption, Potential Error, Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section in order to avoid change position during the operating - Updated surgeon preference sheet before the surgery
Surgeon attempt to adjust the light many times without help	- Failure coordination between the surgeon and the assistant nurses	Disruption, Potential Error, Delay	- Undertake better coordinated between surgeon and assistant surgeon
Surgeon ask nurse pick up the mobile phone	- The operating member received the mobile phone during the operation	Disrupt, Potential Error, Delay	- Introduce OR protocol that requires mobile phones are left at the front reception of theatre with staff taking messages for surgeons and other staff to collect after the surgery

In surgery case A, again, patient's positioning was not adequate which caused the surgeon to adjust patient's head eight times. This can have a high potential for surgery error. Moreover, the type of delay can be reduced considerably where there are no students and there is an experienced assistant surgeon. It is considered that training medical students is part of the hospital responsibility. However, the time of training students can be reduced if the assistant surgeon has enough experience to handle the explanation to the students and answer their questions. In addition, the surgeon could need to explain issues to the assistant surgeon.

However, in surgery case A, the scrub nurse handled and organised the instruments very well and mainly followed the motion economy principles 1 and 2. Further, there were no sharp instruments and used sponges scattered randomly around the patient's anatomy area. The scrub nurse collected these in a timely fashion, and the motion economy principles 1, 2, 3, 4, 6, 9 and 10 were applied by the scrub nurse and surgeon. However, other cases observed in the operating room did not show similarly efficient motion coordination.

Surgery Case B

Summary statistics for surgery case B are as follows:

- Patient arrival time to pre-admission clinic: 6:45 am
- Patient arrival to pre-operative holding area: 7:46 am
- Patient arrive to anaesthetic bay: 8:08 am
- Patient moved to OR: 8:26 am
- OT session ended and patient was out at: 11:08am
- Total session time: 162 minutes

As indicated in Table 4.4, surgery case B had a total session time of 162 minutes, of which 41.8 were non-value adding. The percentage of preventable delay was total preventable time divided by total surgery time, which shows a 25.80 percent non-value adding activity that could be prevented by systematically minimising non-value adding activities. The major reasons for delay and disruption in surgery case B were the following (see observation sheet in Appendix 4 for details):

- Patient's positioning was not adequate to surgeon and affected the surgeon's performance throughout the whole surgery.
- Surgeon repeatedly asked for new materials and suitable tools and materials to be brought from outside the operating room.
- Inefficient way of handling tools by the scrub nurse.
- Counting instruments and sponges many times (more than usual).
- Surgery tools/instruments scattered around anatomy area. This creates delay as a result of searching for the instruments around the anatomy area by the surgeon and scrub nurse.

Table 4.4: Summary of preventable delay (surgery case B)

Activities	Units	Adjusting factor	Total preventable delay	Reasons
⓪	25	0%	0	
①	106	20%	21.2	- Surgeon uncomfortable with patient's poisoning throughout the whole surgery; - scrub nurse does not move her hands efficiently;
②	9	40%	3.6	- Counting instruments and sponges many times (more than usual); - Scrub nurse does not move her hands efficiently
③	0	60%	0	
④	0	80%	0	
D_0	14	100%	14	- Surgeon asks for replacing tools; - Surgeon asks for extra material; - Surgeon and nurses search for missing instruments around the drape area
D_1	0	80%	0	- searching and bringing suitable tools from outside; - searching and bringing required material
D_2	2	60%	1.2	- searching and bringing suitable tools - searching and bringing required material - searching missing instruments around the drape area
D_3	3	40%	1.2	- Searching and bringing suitable tools - Searching and bringing required material
D_4	3	20%	0.6	- Surgeon moves to different location - Searching and bringing tools
Total	**162**		**41.8**	

% Preventable delay =41.8/162=25.80%

The details of the non-value adding activities and delays are summarised in Table 4.5. Specifically, the table presents non-value added activities and delays, their causes, and the effect of the delay, as well as the recommended actions to prevent the observed non-value added activities and delays.

Table 4.5: Non-value added Activities analysis for Surgery B

Non-value added Activities	Cause	Effect	Required action
Scrub nurse does not manage the instruments efficiently	- Lack knowledge of the role of the scrub nurse	Delay	- Education training of the nurses (apply Motion principle 1,2,3)
Surgeon moves around operating theatre table	- Positioning of the patient prevents surgeon comfortably observing the anatomy area	Disruption, Potential Error, Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section in order to avoid change position during the operating - Update surgeon preference sheet before the surgery
Surgeon asks for bringing back suitable instruments	- Failure to record completed specifications and confirm instruments in advance	Delay	- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid the missing and unsuitable material, equipments, and facilities - Undertake better Coordinated between surgeon and nurses
Nurse goes outside to bring back instruments	- The sterile stock room is long distance to operating room	Delay	- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid the missing and unsuitable material, equipments, and facilities during the surgical operation - Use coding system to record specification of material, equipments, and facilities
Surgeon adjust chair and table during surgery	- The table did not adjust properly and the chair is not comfortable	Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section in order to avoid re-adjust instruments - Provide a chair of the type and height to permit good posture by apply motion principle 4,6,8,9, 17
Counting instruments and used sponges many times (more than usual)	- Sharp instruments and used sponges are scattered randomly around anatomy area	Disruption, Potential Error, Delay	- Training recorrect use of mayo table (apply Motion principle 4,6,8,9,10,11,14)

4.3.2 Analysis of all surgery cases observed

A total of 22 surgeries were observed in the study. The causes of delay and inefficient activity are summarised next. Although the causes of delay and inefficient activity are diverse, the researcher has summarized them into three broad categories as related to *coordination, motion economy* and *social factors.* A summary of the NVA activities in all the 22 surgeries are provided on Table 4.7.

a. NVA activities related to coordination

Some delays were caused by unavailability of technicians or anaesthetist to undertake the activities required for the operation to start. At times, operating room wardsmen were unavailable. This caused delays in cleaning after the last operation and the patient having to wait in the Anaesthetic Bay. Unavailability of a surgeon also caused patients to wait in the Anaesthetic Bay. Similarly, radiographer unavailability was caused by failure to inform the radiographer in advance. This lead to disruption and delay in the work of surgeons, as well as for the rest of the OR team. At times the OR also needs to wait for the anaesthetist, which leads to a delay in the start of an operation. This is the result of no one having the presence of mind to inform the preoperative department that the patient could be sent to the OR. Unavailability of equipment (such as recovery bed) was another cause of NVA activities. This occurs due to failure to confirm bed availability within an adequate timeframe and, therefore, leads to a delay in sending the patient to recovery and, thus, a delay in the operation of next patient. In some of the cases, less efficient handling of activities took place when wardsmen were unavailable for patient transport. Nurses performed the transportation and movement of the patient, which was less efficient that of a wardsman. This affected the preoperative department, anaesthetist room and OR which, in turn, led to a delay in initiating the call by the OR. This was caused by the fact that there was a delay in making a call to the wardsman. In some cases, wardsmen were busy with other jobs and, overall, there seems to be shortage of wardsmen.

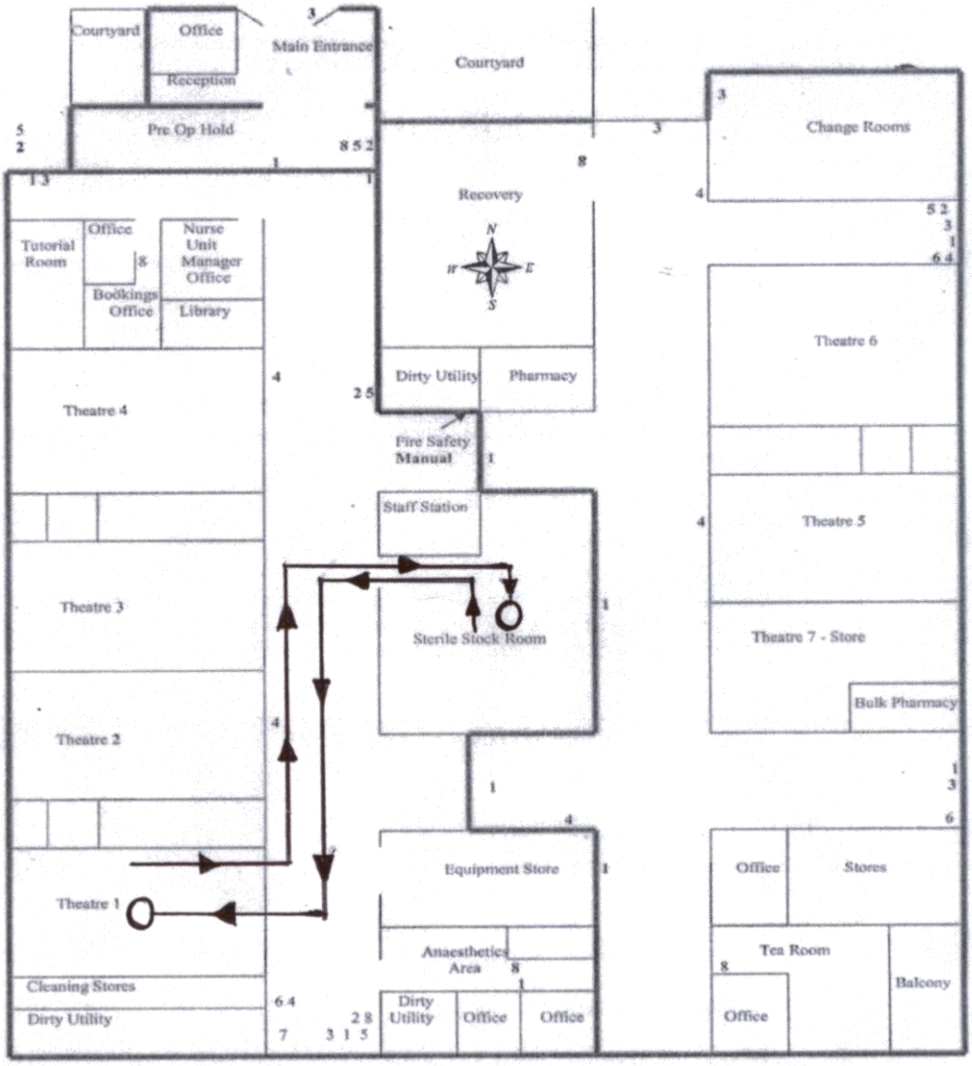
Operating theatre preparations were not completed in time in some cases because of a failure to confirm instrument availability. Unavailability of the X-ray machine (due to a failure to bring in the machine) also led to disruption and delay in surgery. In some cases, nurses rushed to collect the correct instruments. Table 4.6 indicates delays caused by unavailability of required instruments during the surgery, a situation that occurred in nine out of the 22 surgeries observed.

Table 4.6: Nurses searching for instruments

Surgery No.	Number of times nurses searching instruments from sterile stock room	Delay in minutes	Total operation time	% of delay to total operating time
3	3 times	6.8 minutes	107	6.36
5	4 times	9.2 minutes	110	8.36
7	3 times	5.4 minutes	80	6.75
9	5 times	10.8 minutes	162	6.67
14	4 times	8.8 minutes	105	8.38
18	2 times	3.2 minutes	71	4.51
19	2 times	3.4 minutes	134	2.54
20	2 times	4.4 minutes	32	13.75
21	3 times	7 minutes	192	3.65
Total	**26 times**	**55.8 minutes**	**993**	**6.77**

The nurses were informed by the surgeon during the surgery that some of the materials demanded were missing or unsuitable. For example, in one of the surgeries, the nurses was required to go to the sterile stock room which is approximately 40 seconds distance from the operating room 1 (see Figure 4.1), plus an average of 1 minute for searching (total of 2.33 minutes average delay). This is a non-value added activity because all the material could have been prepared in advance.

Figure 4.1: Floor plan of Toowoomba Hospital Operating Theatre Suite



Legend:	1	Fire doors	5	Fire extinguishers
	2	Fire hoses	6	Fire phones
	3	Exits	7	Evacuation pods
	4	Alarms	8	Fire blankets

Incomplete/wrong consent forms also caused some delay in the OR. Failure to enter data in all relevant fields appears to be the cause of the problem. The consent form on one occasion was found to relate to another patient. Thus, in this situation, the OR needed to contact the preoperative area to change the form or ask for more detail. Errors in some activities contributed to the causes of NVA activities. For example, an unsuitable injection was given, that is, the pre-operative holding area applied the injection incorrectly. This subsequently delayed the work of the anaesthetist. In another case, wrong/unsuitable attachment for patient was the cause and required reattaching the right instruments—delaying the work of the surgeon.

In another surgery, the surgeon changed the operating position because she was uncomfortable with the height of the operating table. This meant the surgeon needed to adjust the advanced equipment for operating usage (e.g. microscope). Checking by a wardsman or technician in advance, or better coordination between the surgeon and the assistant nurses would help prevent this problem. Disruption and delay in surgery could result which, in turn, may raise the risk of error in the surgery and impact on patient outcomes.

In some other surgeries, trainee students at times caused disruption because the surgeon was teaching the medical students throughout the surgery via oral explanation, and explaining and discussing the cases. Disruption and delay in surgery could, again, result in errors, and risk to the patient. Telephone disruption also occurred in some cases when some operating team members received mobile phone calls during the operation. In some other cases, it was apparent that the surgeon could not concentrate on the surgery because staff within the operating room continued their conversations for a long time. Disruption and surgery delay could follow as a result of these issues and again impact on surgery errors and risk to the patient.

Unavailability of pathology results prior to surgery led to delay in the surgeon’s work. Also, in some cases, nobody assisted the surgeon to get dressed because the nurses were busy on other tasks. This type of situation delays surgery and potentially increases the risk for patient. On another occasion, the surgeon called for assistance from a high skilled surgeon because the surgeon encountered a difficult case during the operation. Disruption and delay could result in such cases which, again, may cause error in the surgery and raise the risk to the patient. This implies the need for more research before surgery starts.

b. NVA activities related to motion economy

In some cases, sharp instruments and used sponges were scattered randomly around anatomy area because the scrub nurse did not collect them in a timely manner and/or the surgeon did not pass them promptly to the scrub nurse. This can also leads to disruption and delay in the work of the surgeon and has the potential to raise errors in the surgery and risk to the patient. Having a specially-designed table close to the surgeon could help minimise this problem.

From the point of view of motion economy principles, the wasted motion is not only time-consuming, but also adds to physical fatigue. Fatigue is the result of reduced body movement and can impact on levels of efficiency. However, the wasted motion by operating theatre staff members was not recorded and included in the statistics of preventable delay because motions of short duration could not be accurately observed.

In the search for possible solutions to the wasted motion, designing better work methods can often be aided by considering the relationship of the worker to the job, the environment, and the hospital of which the worker is a part. The surgeon in the operating theatre, for instance, may perform work which is entirely manual or may be aided by tools, machines, and equipment. As mentioned in the literature review, the principles of motion economy that are highly applied in the manufacture settings are equally applicable in a healthcare setting. Phillips (2004) espoused the application of time and motion economy study principles in such a setting. Barnes (1949) presented motion economy as three subdivisions: the use of the human body, arrangement of the work place, and design of tools and equipment. This thesis focuses mainly on the principles associated with the use of the human body, and arrangement of the workplace to solve causes of the non-value added activities that were discovered during the observation in the operating theatre.

c. NVA activities related to social factors

Some of the non-value added activities identified in the study relate to social aspects such as interruptions by students (asking questions), operating room members causing disruption by talking during the operating, and mobile phone calls causing interruption. Most of these NVA activities could be prevented by introducing a comprehensive OR protocol and policy; because in a socio-technical setting, clear statement of rules enhances efficiency of team members (Appelbaum 1997).

Table 4.7: Summary of Non-Value Added Activities

Non-Value Added Activities	Causes	Effects	Recommended Solutions
Surgeon makes explanations to assistant about patient's health condition	- The explanation was not made in advance	Delay	- This type of communication should be done before the start of the surgery through better coordination
Surgeon adjust operating theatre table height during the surgery	- Operating theatre table not adjusted at the proper height before the operation	Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section by updating surgeon preference sheet in advance
Surgeon prepares and drapes the patient without assistance	- Non attendance of OR staff including (nurses, and wardsmen)	Delay	- Require better coordination between OR staff
Surgeon asking for help regarding equipment	- Equipment not adjusted properly in advance	Delay	- Require better coordination between OR preparation team and surgeon by adjusting and testing equipment in advance
Surgeon stop operating to explain something to assistant surgeon and students	- Student asking questions	Delay	- Experienced assistant surgeon could help answer the questions
Students and Anaesthetist keep talking during the surgery	- Personal	Disruption, Delay Potential Error	- Require a protocol for students and theatre staff to read and understand before they attend theatre
Surgeon re-adjusting the head of the patient many times	- Patient's positioning is not adequate - Unsuitable attachment	Disruption, Error Delay	- Updated surgeon preference sheet before the surgery
Surgeon attempt to adjust the light many times without help	- Failure coordination between the surgeon and the assistant surgeon	Disruption, Potential Error, Delay	- Require better coordination between surgeon and assistant surgeon
Surgeon asks nurse pick up the mobile phone	- The operating member received mobile phone call during the operation	Disrupt, Potential Error, Delay	- Introduce OR protocol that requires mobile phones are left at the front reception of theatre with staff taking messages for surgeons and other staff to collect after the surgery
Scrub nurse does not manage the instruments efficiently	- Lack knowledge of the role of the scrub nurse	Delay	- Education training of the nurses, especially in time and motion study (apply Motion principle 1,2,3)
Surgeon moves around operating theatre table	- Positioning of the patient prevents surgeon to comfortably observing the anatomy area	Disruption, Potential Error, Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section in order to avoid change position during the operating - Update surgeon preference sheet before the surgery

Non-Value Added Activities	Causes	Effects	Recommended Solutions
Surgeon searching for instruments	- Failure to have the correct instruments available for the surgical procedure	Delay	- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid the missing and unsuitable instruments
Surgeon asks for replacement instruments	- Failure to record completed specifications and confirm instruments in advance	Delay	- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid the missing and unsuitable instruments - Require better coordinated between surgeon and nurses
Nurse goes outside to bring back instruments	- The sterile stock room is long distance from operating room	Delay	- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid the missing and unsuitable material, equipments, and facilities during the surgical operating - Use coding system to record specification of instruments
Surgeon adjust chair and table during operating	- The table did not adjust properly and the chair is not comfortable	Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section in order to avoid re-adjust instruments - Provide a chair of the type and height to permit good posture
Counting instruments and used sponges many times (more than usual)	- Sharp instruments and used sponges are scattered randomly around anatomy area	Disruption, Potential Error, Delay	- Training recorrect use of mayo table (apply Motion principle 4,6,8,9,10,11,14)
Surgeon and nurses searching for instruments	- Instruments slipped under surgery drape	Disruption, Potential Error, Delay	- Provide training staff on motion economy
Awaiting set up of operating theatre	- Late arrival of a team member; - Failure to confirm instruments availability (nurses rush to collect the right instruments)	Delay	- Undertake better coordination through communication between setup term and OR supervisor should be maintained before the OR set up
Awaiting Technician/coordinator	- Technician/coordinator late to enter OT	Delay	- undertake better coordination through communication between technician and OR supervisor should be maintained during the OR set up
Transport or move patient without Wardsmen	- Delay in initiating the call by OR - Wardsmen's delay in responding to the call - Wardsmen busy in other mission	Delay	- Undertake better coordination through call wardsmen before the start of emergency time (post-anaesthesia period)
Anaesthetist nurse ask more	- Failure to enter data in all relevant	Delay,	- Undertake better coordination between pre-operative holding area

Non-Value Added Activities	Causes	Effects	Recommended Solutions
information in relation to consent form	fields	Disruption, Potential error	and operating room - Missing data and unfilled field can be easily detected by developing consent form that can be scanned and digitised
Await Anaesthetist	- Anaesthetist late to enter AR	Delay	- Make better coordination through communication between Anaesthetist and OR supervisor should be maintained during the OR set up
Patient need to waiting in the Anaesthetist room	- Delay in cleaning after the last operation	Delay	- Require better coordination between OT team
Awaiting surgeon	- Surgeon late to enter OR	Delay	- Make better coordination through communication between surgeon and OR supervisor should be maintained during the OR setup
Reattaching the correct attachment to the operating theatre table	- Receiving wrong or unsuitable attachment - Surgeon fails to record or update his preference sheet for use in set up	Delay	- Facilitate direct information flow between surgeon's office and operating room preparation section in order to avoid receive wrong or unsuitable attachment - Use coding system to record specification of attachments
Awaiting Radiographer	- Failure to inform radiographer in advance	Disruption, Delay	- Schedule the availability of radiographers in consistency with the surgery schedule
Awaiting X-ray machine	- Failure to bring the machine in time	Disruption, Delay	- Schedule the availability of X-ray machine in consistency with the surgery schedule
Change unsuitable trolley bed to move the patient	- The patient is overweight	Delay	- The patient's information (bariatric patient) that may cause delay during transportation should be identified and should be accessible to relevant staff. - Require better coordination between OT team
Surgeon get dressing alone	- The nurses are busy on others things	Delay, Potential Error	- Require better coordination between OT team
Patient await recovery bed	- Failure to confirm bed availability within adequate time	Delay	- Confirm bed availability in advance - Require better coordination between recovery and OR
Surgeon await pathology results	- Failure to have the test results before the surgery	Delay	- Direct communication between lab and OT should be maintained - Checklist for each category of surgery operation can be used to remind surgeon on the required tests

Summary statistics of the total session time, as well as the mean and standard deviations of the non-value adding activities, are summarized in Table 4.8 (a) and (b). Table 4.8 (a) presents descriptive statistics for value adding and non-value adding units (see the total 22 surgery cases statistic tables in Appendix 5). In this table both the value adding and non value adding activities are presented in units as observed, i.e. without adjustment. Total session time for all the cases was 1496 units, with a mean of 68 and standard deviation of 48.41 units. Mean non-value adding delay was 7.73, 1.41, 1.91, 1.59 and 1.77 units for D_0, D_1, D_2, D_3 and D_4 respectively. The mean operating times were 838, 249, 73 and 47 respectively for⓪,①,②,③ and ④.

Table 4.8 (b) presents the total session time, the preventable delay in value adding operation, preventable delay in non-value adding operation, total delay time, and proportion of total delay to total session time. Delay and total session time were measured in minutes. The longest session time in the cases observed was 192 minutes and the shortest was 10 minutes; and the average session time was 68 minutes. Total preventable delay, i.e. in both value adding activities and non-value adding activities, was 371.8 minutes for all the surgeries and mean and standard deviation of total delay was 16.90 and 10.77 minutes respectively. The total delay ranged between 41.2 minutes (surgery case 9) and 2 minutes (surgery case 22). The percentage of preventable delay ranged between 71.11% (surgery case 1) and 14.93% (surgery case 18). Results demonstrated that delay caused an increase in surgical time and forced surgeons and patients to endure an unnecessarily average delay of 25.68% (or about 26%) of the total surgery time. Such additional time could be utilised to deal with the pressure of emergency cases and to reduce the waiting lists for elective surgery.

Table 4.8 (a): Descriptive statistics for value added and non-value added units

Surgery No.	**Value Added activities in Unit**					**Non-Value Added activities in Unit**					**Total session time**
	⓪	①	②	③	④	D_0	D_1	D_2	D_3	D_4	
1	3	5	2	0	1	21	0	2	2	0	36
2	10	11	3	0	14	9	1	0	1	1	51
3	64	4	6	6	0	13	3	5	5	1	107
4	21	12	4	3	6	7	1	4	0	0	58
5	58	11	3	4	1	11	2	0	4	7	110
6	91	7	1	0	0	5	4	0	0	1	25
7	56	5	6	1	4	4	0	3	0	1	80
8	34	4	7	0	3	7	1	0	5	3	64
9	25	106	9	0	0	14	0	2	3	3	162
10	21	3	6	3	2	6	3	0	1	1	46
11	21	5	0	6	2	2	0	3	0	3	29
12	16	3	1	0	3	3	1	3	1	0	43
13	26	11	5	4	1	3	0	0	4	1	55
14	64	12	0	6	3	6	2	0	5	7	105
15	5	2	1	1	1	5	1	0	0	1	17
16	14	3	0	2	0	1	0	2	0	1	23
17	32	4	1	2	0	3	0	2	1	1	46
18	41	11	2	2	0	6	3	5	1	0	71
19	91	9	1	4	4	19	0	5	0	1	134
20	16	5	1	2	1	3	1	2	0	1	32
21	125	13	13	1	1	22	7	4	2	4	192
22	4	3	1	0	0	0	1	0	0	1	10
Total	**838**	**249**	**73**	**47**	**47**	**170**	**31**	**42**	**35**	**39**	**1496**
Average	**38.09**	**11.32**	**3.32**	**2.14**	**2.14**	**7.73**	**1.41**	**1.91**	**1.59**	**1.77**	**68.00**
Standard Deviate	**32.59**	**21.47**	**3.37**	**2.10**	**3.12**	**6.37**	**1.74**	**1.87**	**1.87**	**2.00**	**48.41**

Table 4.8 (b): Descriptive statistics of the preventable delay in value added and non-value added activities

Surgery No.	Total session time	Preventable delay in Value Added activities					Preventable delay in Non-Value Added activities					Total Delay time	% Preventable delay
		⓪	①	②	③	④	D_0	D_1	D_2	D_3	D_4		
1	36	0	1	0.8	0	0.8	21	0	1.2	0.8	0	25.6	71.11%
2	51	0	2.2	1.2	0	11.2	9	0.8	0	0.4	0.2	25	49.02%
3	107	0	0.8	2.4	3.6	0	13	2.4	3	2	0.2	27.4	25.61%
4	58	0	2.4	1.6	1.8	4.8	7	0.8	2.4	0	0	20.8	35.86%
5	110	0	2.2	1.2	2.4	0.8	11	1.6	0	1.6	1.4	22.2	20.18%
6	25	0	1.4	0.4	0	0	5	3.2	0	0	0.2	10.2	40.80%
7	80	0	1	2.4	0.6	3.2	4	0	1.8	0	0.2	13.2	16.50%
8	64	0	0.8	2.8	0	2.4	7	0.8	0	2	0.6	16.4	25.63%
9	162	0	21.2	3.6	0	0	14	0	1.2	1.2	0.6	41.8	25.80%
10	46	0	0.6	2.4	1.8	1.6	6	2.4	0	0.4	0.2	15.4	33.48%
11	29	0	1	0	3.6	2	2	0	1.8	0	0.6	11	37.93%
12	43	0	0.6	0.4	0	2.4	3	0.8	1.8	0.4	0	9.4	21.86%
13	55	0	2.2	2	2.4	0.8	3	0	0	1.6	0.2	12.2	22.18%
14	105	0	2.4	0	3.6	2.4	6	1.6	0	2	1.4	19.4	18.48%
15	17	0	0.4	0.4	0.6	0.8	5	0.8	0	0	0.2	8.2	48.24%
16	23	0	0.6	0	1.2	0	1	0	1.2	0	0.2	4.2	18.26%
17	46	0	0.8	0.4	1.2	0	3	0	1.2	0.4	0.2	7.2	15.65%
18	71	0	2.2	0.8	1.2	0	6	2.4	3	0.4	0	16	22.54%
19	134	0	1.8	0.4	2.4	3.2	19	0	3	0	0.2	30	22.39%
20	32	0	1	0.4	1.2	0.8	3	0.8	1.2	0	0.2	8.6	26.88%
21	192	0	2.6	2.6	0.6	0.6	22	5.6	2.4	0.8	0.8	38	19.79%
22	10	0	0.6	0.4	0	0	0	0.8	0	0	0.2	2	20.00%
Total	**1496**	0	49.8	26.6	28.2	37.8	170	24.8	25.2	14	7.8	**384.2**	**25.68%**
Average	**68.00**	0.00	2.26	1.21	1.28	1.72	7.73	1.13	1.15	0.64	0.35	**17.46**	
Standard Deviate	**48.41**	0.00	4.29	1.08	1.26	2.50	6.37	1.39	1.12	0.75	0.40	**10.53**	

Table 4.9: Main causes for the preventable delay

General Area	1	2	3	4	5	6	7	8	9
Consent form	9.2	6.46%	0.61%	5.9	2.44%	0.39%	15.1	3.93%	**1.01%**
Protocol & policy	8.8	6.18%	0.59%	10.1	4.18%	0.68%	18.9	4.92%	**1.26%**
Surgeon preference sheets	15.9	11.17%	1.06%	33.6	13.90%	2.25%	49.5	12.88%	**3.31%**
Motion economy	58.3	40.94%	3.90%	73.7	30.48%	4.93%	132.0	34.36%	**8.82%**
Coordination	50.2	35.25%	3.36%	118.5	49.01%	7.92%	168.7	43.91%	**11.28%**
Total	142.4		9.52%	241.8			384.2		**25.68%**

1) Preventable delay in Value Added activities
2) % of preventable delay in Value Added activities
3) % of preventable delay relative to the total surgery time (1496 minutes)
4) Preventable delay in Non-Value Added activities
5) % of preventable delay in Non-Value Added activities
6) % of preventable delay relative to the total surgery time (1496minutes)
7) Total preventable delay (column 1 + column 4)
8) % of total preventable delay
9) % of total preventable delay relative to the total surgery time (1496 minutes)

From the summary of Non-Value Added Activities table (Table 4.7), this study summarizes the general causes of delay and disruption as Consent form; Protocol & policy; Surgeon preference sheets; Motion economy; and Coordination. After summarizing the observation sheets of the 22 surgery cases, the minutes of Preventable delay in Value Added activities for each cause are listed in column 1. As it is shown in the table, the total minutes of Preventable delay in Value Added activities was 142.4. Column 4 shows the minutes of Preventable delay in Non-Value Added activities for each cause as a total of 241.80 minutes. The total minutes of Preventable delay in Value Added activities and Non-Value Added activities for each cause as shown in column 7 were 384.2.

In addition, the total surgery time of 22 surgery cases was 1496 minutes. In column 2, it indicates the percentage of each cause of preventable delay minutes in Value Added activities (142.4). Column 3 indicates the percentage of each cause of preventable delay minutes in Value Added activities in total minutes of 22 surgery cases (i.e. 1496 minutes). Column 5 presents the percentage of each cause of preventable delay in minutes of Non-Value Added activities (i.e. 241.8). Column 6 shows the percentage of each cause of preventable delay minutes in Non-Value Added activities in total minutes of 22 surgery cases time (i.e. 1496 minutes). In column 8, the table presents the percentage of each cause of preventable delay minutes in Value Added activities and Non-Value Added activities in total minutes of 384.2. In column 8, it shows the percentage of each cause of preventable delay minutes in Value Added activities and Non-Value Added activities in total minutes of 1496.

From this table (Table 4.9), it is clearly evident that the major causes of delay and disruption is lack of coordination and lack of applying motion economy practices inside the ORs.

4.4 Summary

This chapter has presented the results of the case studies undertaken in the operating theatre of Toowoomba Health Services. The choice of the case emanated from the increase in waiting lists in hospitals nowadays and the enhanced understanding in the sector of the need to minimise wasted time and improve patient care. The NVA activities were categorised into coordination related and motion economy related, depending upon the causes and recommended solutions to minimize NVA activities. Therefore, at a general level, the lack of coordination between departments, lack of coordination among team members of operating theatre and less efficient handling of activities in the operating theatre were major sources of NVA activities. The study indicates that the NVA activities could be prevented via better coordination of work among departments and team members, and provision of motion economy training to OR team members, as well as how the introduction of a comprehensive OR protocol would help eliminate NVA activities.

CHAPTER 5 – CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions emanating from the study of case study evidence presented in the previous chapter. The following section summarises the thesis, followed by Section 5.2, which provides the conclusions of the study in Section 5.3 and recommendations in Section 5.4. Section 5.5 follows with a discussion on the limitation of the study. The Section 5.5 provides the study's contributions to theory and practice, followed by the final section, which provides suggested directions for further research.

5.1 Summary

This study has examined how non-value added activities could be minimized by using the concept of adapted lean thinking within the Operating Theatre Management Process (OTMP). Activities within the operating room have been studied, based on a case study of Toowoomba Health Service (THS), a public regional hospital in Queensland, Australia. Activities within the operating room relating to 22 surgery cases were observed with a view to identifying the preventable delay in both value added and non-value added activities.

A combination of theories, concepts and techniques has been applied to gain insights from different perspectives, and to help capture a comprehensive set of relevant issues. The theoretical framework of this study combines two theories: socio-technical system and coordination theory. From the perspective of socio-technical system theory, each activity within OTMP has two types of elements: social element and technical element. Coordination theory on the other hand, concerns the coordination between various elements of the activities. In the context of healthcare, it considers coordination between surgery staff (social factors) in their implementation of surgery (technical factors). Overall, coordination theory provides insights into how the complex interdependencies between and within activities could be managed. Time and motion study has been employed to analyse activities in terms of operation, transportation, delay and monitoring within the operating room. Subsequently, adapted lean thinking (i.e. lean thinking adapted to the context of a healthcare setting) has been employed as an integrating concept to recognise the non-value added activities and identify preventable delay and disruption within both value added and non-value added activities. Identifying the preventable delay within the value added activities inside the operating rooms is one of the most important contributions of this study.

Data were collected through observation of operating theatre activities, review of archival records and interviews with the liaison officers of THS, as well as the relevant operating theatre team members. In the first stage of this research, interviews, printed and electronic documentation and archival records were used to gather the flow of information and resources and to understand control requirements for process activities. In the second stage, direct observations were conducted by the researcher to identify the time spent on activities in the OTMP.

5.2 Conclusions

This study addressed the major research question raised in chapter one: *How can non-value added activities be identified and reduced using adapted lean thinking within the operating theatre management process (OTMP)?* The study provides some evidence that the application of adapted lean thinking in a healthcare setting would help minimize the non-value added activities and make the system more efficient. Improving the performance of operating theatres is central to improving services for patients. More efficient use of operating theatres will improve service to patients; however, delays and inefficient performance within operating theatres remain a concern in healthcare.

It has been highlighted that adapting lean thinking has the potential for increased efficiency in a healthcare setting. As the healthcare environment has both social and technical dimensions, there needs to be a theoretical framework that enables taking into account both these aspects when adapting lean thinking. A combined theoretical framework has been employed in this study to undertake the case study and examine the results. Two theories, that is, socio technical systems theory and coordination theory, were employed to formulate the conceptual framework. STS theory has been used to explain the social and the technical aspects of the processes involved in healthcare activities. Coordination theory was employed to discern the possible interdependencies among activities, components and work groups.

Analysis of results from the 22 cases reveals that delay caused an increase in surgical time and forced surgeons or patients to unnecessarily wait for 25.68% of the total surgery time. Such additional time could be used to deal with the pressure of emergency cases and with the admission of elective surgery patients. More specifically, the major preventable delays that have been identified through the case study on the THS were:

- Sometimes surgeon preference sheets were not detailed enough. Lack of detail creates the following preventable delay:
    - (a) Bringing incorrect and unsuitable instruments and materials into the operating theatre.
    - (b) Incorrect positioning of patients.
- The surgical team wasted considerable time re-adjusting the operating theatre table, equipment, patient’s positioning, etc.
- The surgical team wasted considerable time searching and/or awaiting for suitable instruments.
- Delays resulted from missing data and unfilled field/s in the consent form.
- Delays in surgery seem to be caused also by the need to wait for staff attendance, recovery bed preparation, and pathology results.
- Inappropriate handling of the instruments and materials, e.g. sharp instruments and used sponges scattered randomly, sometimes around

anatomy areas, causing nurses to unnecessarily search and count items repeatedly.

- Scrub nurses failed to arrange the instruments correctly and efficiently on the mayo table.
- Various unnecessary disruptions resulted from trainees in attendance.
- Mobile phone call interruptions also create delays and disruption in some cases.
- The unrelated matters of conversation between surgery staff inside the operating room sometimes caused delay and disruption.

5.3 Recommendations

With the application of lean thinking, the results suggest that THS needs to take the following actions to minimize preventable delays:

- The surgeon preference sheets should have complete specification and details of the instruments and materials, etc. The sheets should also have a complete description of the patient's positioning.
- It would be preferable for the surgeon preference sheets to be updated as soon as possible to facilitate direct information flow between the surgeon's office and operating room preparation staff.
- Facilitate direct information flow between surgeon's office and store/inventory control section in order to avoid missing and unsuitable materials, instruments, etc. during surgery.
- Employ a coding system to record specification of material, equipment, and facilities.
- Store the most required and in-demand material, instruments, etc. in a small cabinet inside the operating room, rather than the central sterile stock room.
- Enhance communication between:
  - (a) Operating room and preoperative holding area
  - (b) Operating room and recovery department
  - (c) Operating room and test lab
- The patient's information (bariatric patient) should be identified and be accessible to relevant staff during transportation to avoid delay.
- Missing data and unfilled field/s can be easily detected by developing a consent form that can be scanned and digitised.
- Scheduling the availability of radiographers/X-ray machine, etc. to be consistent with the surgery schedule.
- Arrange training courses for nurses on :
  - (a) correct use of scrub table mayo table, e.g. instruments should be located within the grasp range of scrub nurse.

(b) motion economy principles that allow scrub nurse to reach for the instruments without wasting time looking and searching.

(c) filling and preparing consent form in pre-operative holding area in order to avoiding missing data and unfilled field/s.

- Video-taping the surgery, with the patient's permission, would enable the tape to be used for teaching purposes and avoid undue interruption from trainees in attendance.
- The use of a comprehensive OR protocol that addresses ethical requirements during the surgery would help to prevent some interruptions, including:

(a) introduction of OR protocol that requires mobile phones be left at the front reception of the theatre, with reception staff taking messages for surgeons and other operating theatre staff to collect after the surgery.

(b) introduce OR protocol for students and theatre staff to read and understand before commencement of theatre.

5.4 Limitations of the study

The results of this study need to be interpreted with caution. Despite success stories, lean advocates in healthcare are experiencing frustrating difficulties in implementing lean initiatives. The application of conventional lean thinking within an environment which is significantly different from manufacturing may become problematic. Lean thinking may not fit easily within the healthcare environment where automation plays a secondary role to experience and skills. In contrast to manufacturing, healthcare services are fully customised and each patient has unique features and health status. Another limitation is that the study is largely based on qualitative analysis in the sense that quantitative models that could possibly help minimize waste have not been employed. Furthermore, the common limitations of case study research methodology and design relating to low external validity apply. Also, as Yin (2003) indicates, generalisability has limited relevance to contexts other than the context studied. Nonetheless, the results of this study are still expected to have relevance to other hospital settings, as hospitals are similarly managed in Queensland (Foo 2006).

5.5 Contributions of the study

The results of the study have some practical and theoretical implications, and these are discussed below.

5.5.1 Contributions to practice

The results of the study have established the need to adopt several important practices, specifically:

- it suggests some causes of wasted time in operating theatres, along with solutions which healthcare institutions could implement;
- institutions in the healthcare industry could apply the methodology employed in this study to undertake similar action research and further minimise waste;

- the study is expected to inform policy makers, that is, government bodies, on the need for healthcare institutions to become more efficient.

5.5.2 Contributions to theory

The present study is expected to contribute the following outcomes to the developing body of literature on the management of healthcare as follows:

- The study introduced a more comprehensive framework under which future research could expand.
- By providing additional empirical evidence on the wasted time and preventable delay and disruption within operating theatre suites, the study provides additional insights into ways of identifying and eliminating waste in operating theatre suites.

5.6 Further studies

The results of this study offer several future research opportunities, in particular:

- A benchmarking based study could be conducted to see if similar sets of NVA activities are observed in most healthcare institutions.
- Consider other aspects of OTMP to better understand the barriers and causes for delays and, thus, reduce long waiting lists.
- As this study is mainly qualitative; quantitative models like linear programming, dynamic programming and queuing models could be employed in future studies to quantify the analysis.

The researcher has achieved the aims of the study by addressing the initial research question and it is hoped that this study will not only achieve improved health information to the sector and the broader community, but also pave the way for further research and solutions on how non-value added activities could be minimized by using the concept of adapted lean thinking within Operating Theatre Management Process (OTMP).

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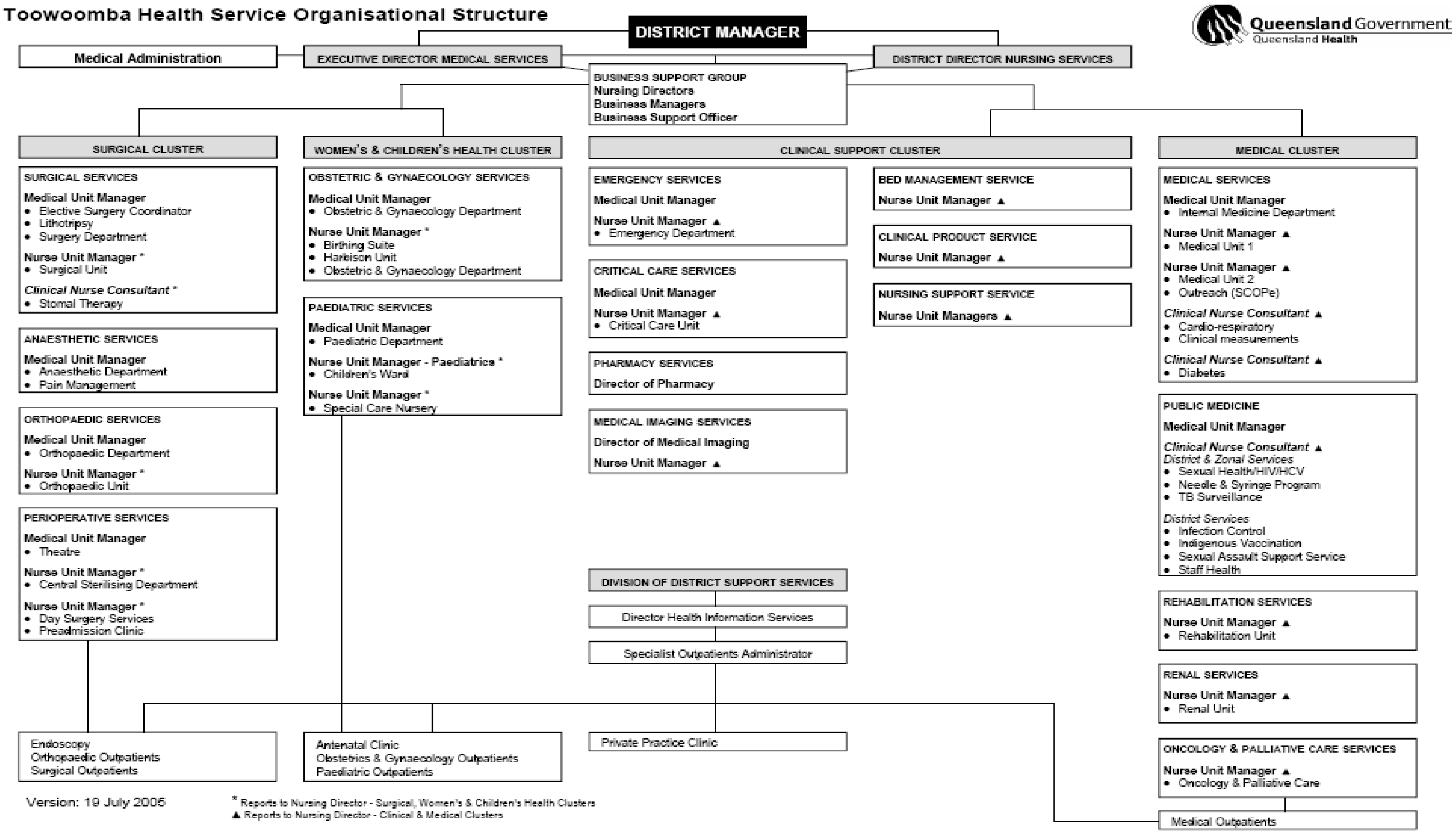
Appendix 1: Organisational Structure of Toowoomba Health Service

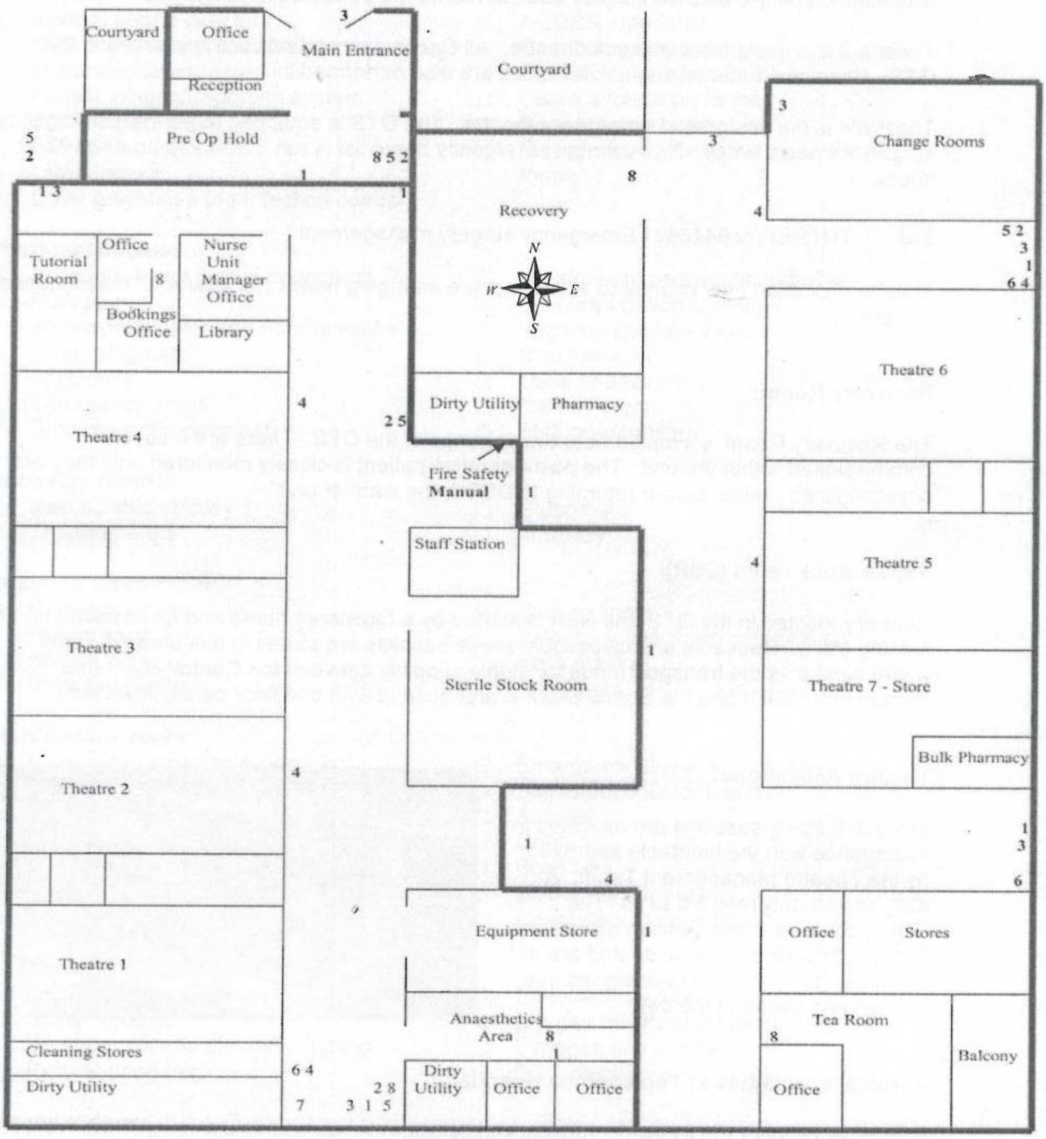


(**Source**: Toowoomba Health Service)

Appendix 2: Plan of Operating Theatre Suite

Operating Theatre Suite Orientation   Version 1 April, 2008

Floor plan of Toowoomba Hospital Operating Theatre Suite:



Legend:	1	Fire doors	5	Fire extinguishers
	2	Fire hoses	6	Fire phones
	3	Exits	7	Evacuation pods
	4	Alarms	8	Fire blankets

📖 THTREProc05359v1 Fire safety in the Operating Theatre Suite

Toowoomba Hospital
Toowoomba and Darling Downs Health Service District   8

Appendix 3: Observation Flow sheet—surgery case A

Note:
□ = monitoring
O = operation
D = delay
→ = transport

Start Time **9 : 48**	Surgeon	Assistant Surgeon	Anaesthetist	Assistant Anaesthetist	Technician	Scrub nurse	Scout nurse 1	Scout nurse 2	Wards man 1	Wards man 2	Type of Delay	Type of operation	*Description*
Minute				→	→				→				Move the patient into the OR
49				**O**	**O**				**O**	**O**			Wardsmen along with the Assistant Anaesthetist and Technician moves patient to the surgery table which is inside the OR
50	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			Anaesthetist and Assistant Anaesthetist are supplying Oxygen to the patient. Technician and wardsmen are covering patient's body with sheet. Meanwhile, scrub nurse is preparing instruments for surgeons. Other two scout nurses are helping scrub nurse preparing instruments. Surgeon and assistant surgeon are monitoring.
51	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			

52	**D**	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	$\mathbf{D_1}$		Surgeon is searching the table to put some items that will be used frequently during the operation.
53	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			Nurses are counting the equipments; others are still supplying oxygen to the patient. (Because this is the second operation, the staffs are not able to prepare everything in advance. But in private hospital, there is another room beside the operating room for preparation. In this case, the nurse is counting the instruments; meanwhile, the Anaesthetist is supplying oxygen to patient. Then the counting time of nurse will not consider as a delay. If patient has been ready to be operated, then the counting time would be consider as a delay)
54	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			
55	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			
56	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			
57	□	□	**O**	**O**	**O**	□	□	□	**O**	**O**			Surgeons are discussing the patient’s circumstances; technician along with wards man cover the sheet onto patient and adjust the operating table (this could be done with surgeon in more efficient way, because surgeons know the exact positioning). Nurses completed the preparation of equipments, and the Anaesthetist also finished the oxygen towards the patient.
58	□	□	**O**	**O**	**O**	□	□	□	**O**	**O**			

59	☐	☐	☐	☐	**O**	☐	☐	☐	**O**	**O**			
10:00	☐	☐	☐	☐	**O**	☐	☐	☐	**O**	**O**			
01	☐	☐	☐	☐	**O**	☐	☐	☐	**O**	**O**			
02	**O**	☐	☐	☐	→	☐	☐	☐	☐	☐	**D_0**		Surgeon starts to adjust the operating table according her preference(patient purported to be ready for surgery)
03	**O**	☐	☐	☐		☐	☐	☐	☐	☐	**D_2**		
04	**O**	☐	☐	☐		☐	☐	☐	☐	☐		②	Surgeon covers the patient's body except the area that is to undergo operation alone. (this could be done with other members in OR during the time when Anaesthetist was supplying the oxygen) (It was noticed that surgeon did not wash her hand after adjusting the surgery table rather than was wearing the sterilised dress (potential error).
05	**O**	☐	☐	☐		☐	☐	☐	☐	☐		②	
06	**O**	☐	☐	☐		☐	☐	☐	☐	☐		②	
07	**O**	☐	☐	☐		☐	☐	☐	☐	☐		②	
08	**O**	☐	☐	☐		☐	☐	☐	☐	☐		②	Surgeon done
09	→	→	☐	☐		☐	☐	☐	☐	☐			Surgeons went out for washing hands (should be done before).
10	→	→	☐	☐		☐	☐	☐	☐	☐			
11	→	→	☐	☐		☐	☐	☐	☐	☐			

12	**O**	**O**	**O**	**O**		□	□	□	□	□			Surgeons are dressing and a nurse is helping.
13	**O**	**O**	**O**	**O**		□	□	□	□	□			
14	**O**	□	□	□		□	□	□	□	□			Surgeon starts to use the equipment.
15	**D**	□	□	□		□	□	□	□	□	$\mathbf{D_0}$		Something wrong with the equipment; surgeon asking for help.
16	**D**	□	□	□		□	□	□	**O**	□	$\mathbf{D_0}$		Wardsman adjust the equipment
17	**D**	□	□	□		□	□	□	**O**	□	$\mathbf{D_0}$		
18	**D**	□	□	□		□	□	□	**O**	□	$\mathbf{D_0}$		
19	**D**	□	□	□		□	□	□	**O**	□	$\mathbf{D_0}$		
20	**D**	□	□	□		□	□	□	**O**	□	$\mathbf{D_0}$		
21	**D**	□	□	□		□	□	□	**O**	□	$\mathbf{D_1}$		
22	**O**	□	□	□		**O**	□	→	→	→			Wardsman and one of the scout nurses went out; surgeon start operation and scrub nurse give the equipments to surgeon
23	**O**	□	□	□		**O**	□						
24	**O**	□	□	□		□	□						Sometimes the scrub nurse is monitoring
25	**O**	□	□	□		**O**	□						

26	□	□	□	□		□	□				**D_0**		Surgeon stop work to explain something to assistant surgeon (seems the assistant surgeon doesn’t have enough experiences and she is learning from the operation)
27	□	□	□	□		□	□				**D_2**		
28	**D**	□	□	□		**O**	→				**D_0**		Scrub nurse bring the wrong injection tool (needle should be longer than supposed to be); scout nurse is asked to bring a new needle.
29	**D**					**O**	→				**D_1**		Scout nurse bring the right needle to scrub nurse, then give to surgeon
30	**O**	□	□	□		□	□					④	Explain to assistant surgeon, meanwhile operating (surgeon spent a lot of time to teach the assistant surgeon who sound not having enough experiences and other three students)
31	**O**	□	□	□		□	□					①	
32	**O**	□	□	□		□	□					①	
33	**O**	□	□	□		□	□					①	Three students keep talking around surgeon (it may affect or interrupt the surgeon)
34	**O**	□	□	□		□	□					①	
35	**O**	□	□	□		**O**	□					①	Assistant surgeon explain something to those students(it may affect or interrupt the surgeon)

36	**O**	□	□	□		□	□					①	
37	**O**	**O**	□	□		□	□						
38	**O**	**O**	□	□		□	□						
39	**O**	**O**	□	□		□	□						
40	**O**	**O**	□	□		□	□				**D_1**		Surgeon is adjusting the patient's head because of heavy cutting (before starting the operation, the surgeon folded a sheet and put it under the patient's head. It may be the main reason that the patient's head kept moving.).
41	**O**	**O**	□	□		□	□						
42	**O**	**O**	□	□		□	□						
43	**O**	**O**	□	□		**O**	□						
44	**O**	**O**	□	□		□	□				**D_4**		Adjusting patient's head
45	**O**	**O**	□	□		□	□						
46	**O**	**O**	□	□		**O**	□						
47	**O**	**O**	□	□		□	□				**D_3**		Adjusting patient's head
48	→	→	□	□		□	□				**D_1**		Surgeon and assistant surgeon turn their position
49	□	□	□	□		□	□				**D_3**		Surgeon explain to assistant something and let the assistant do the operating
50	□	**O**	□	□		**O**	□					①	

51	□	□	□	□		□	□				$\mathbf{D_4}$		Surgeon explains in more details again.
52	□	**O**	□	□		□	□					①	Assistant surgeon is doing the operation
53	□	**O**	□	□		□	□					①	
54	□	**O**	□	□		□	□					①	
55	□	**O**	□	□		**O**	→				$\mathbf{D_0}$		Scout nurse go out to bring the missing equipment
56	**O**	□	□	□		**O**	**O**				$\mathbf{D_2}$		Scrub nurse give the tool to surgeon; surgeon operate again
57	**O**	□	□	□		□	□						
58	**O**	□	□	□		□	□						
59	□	**O**	□	□		□	□				$\mathbf{D_0}$		Assistant surgeon adjust the table for surgeon
60 (11:00)	□	□	□	□		□	□				$\mathbf{D_1}$		Surgeon adjust the chair(the chair is not special for the surgeon, the surgeon felt uncomfortable during the operating)
1	**O**	□	□	□		□	□						
2	**O**	□	□	□		□	□						
3	**O**	□	□	□		□	□						
4	**O**	□	□	□		□	□						
5	□	□	□	□		**O**	□						Scrub nurse change the needle for surgeon (Necessary)
6	**O**	□	□	□		□	□						
7	**O**	□	□	□		**O**	□						Changing tools for surgeon (Necessary)

8	**O**	□	□	□		□	□						
9	**O**	□	□	□		□	□						
10	**O**	□	□	□		□	□						
11	**O**	□	□	□		**O**	□						
12	**O**	□	□	□		□	→						Scout nurse went outside (don’t know the reason)
13	□	□	□	□		□	□				$\mathbf{D_0}$		Surgeon stops, then is teaching the students something.
14	□	□	□	□		□	□				$\mathbf{D_0}$		
15	□	□	□	□		□	□				$\mathbf{D_0}$		
16	□	□	□	□		□	□				$\mathbf{D_0}$		
17	□	□	□	□		□	□				$\mathbf{D_0}$		Surgeon need equipment connection, but something is wrong with the machine, then ask for help
18	□	□	□	□		□	□				$\mathbf{D_0}$		
19	□	□	□	□		□	□				$\mathbf{D_4}$		Finally, assistant surgeon solves the problem
20	**O**	□	□	□		□	□						
21	**O**	□	□	□		□	□						
22	**O**	□	□	□		□	□						
23	**O**	□	□	□		□	□						

24	**O**	□	□	□		□	□						
25	**O**	□	□	□		□	□						
26	**O**	□	□	□		□	→						Scout nurse went out and changed a new scout nurse(not sure the reason)
27	**O**	□	□	□		□	□						
28	**O**	□	□	□		□	□						
29	**O**	□	□	□		□	□						
30	**O**	□	□	□		□	□						
31	**O**	□	□	□		□	□						
32	**O**	□	□	□		□	□						
33	**O**	□	□	□		□	□						
34	**O**	□	□	□		□	□				$\mathbf{D_0}$		Surgeon adjusts the patient’s head
35	**O**	□	□	□		□	□				$\mathbf{D_4}$		
36	**O**	□	□	□		□	□						
37	**O**	□	□	□		□	□						
	O	□	□	□		□	□						

38	**O**	□	□	□		□	□					③	Surgeon adjust the light (the assistant surgeon is much higher than surgeon; she pushed the power light to a certain position when surgeon didn’t need the light. The surgeon adjusts the power light by herself afterward. But cost time and raised the risk for both of patient and her due to the high position of the light)
	O	□	□	□		□	□						
39	**O**	□	□	□		□	□						
40	□	□	□	□		□	→				**D_0**		Scout nurse collect the demand instruments for surgeon
41	□	□	□	□		□	→				**D_0**		
42	□	□	□	□		□	→				**D_0**		
	□	□	□	□		□	→				**D_2**		
43	**O**	□	□	□		□	□						
44	**O**	□	□	□		□	□						
	O	□	□	□		□	□						
45	**O**	□	□	□		□	□						
46	**O**	□	□	□		□	□						
47	□	□	□	□		□	□				**D_0**		Surgeon discusses with assistant surgeon. The students around them ask questions.

48	**O**	☐	☐	☐		☐	☐						
49	**O**	☐	☐	☐		☐	☐						
50	**O**	☐	☐	☐		☐	☐						
51	**O**	☐	☐	☐		☐	☐						
52	**O**	☐	☐	☐		☐	☐				**D_1**		Adjust head (minor adjustment)
53	**O**	☐	☐	☐		☐	☐						
54	**O**	☐	☐	☐		☐	☐						
55	**O**	☐	☐	☐		☐	☐						
56	**O**	☐	☐	☐		☐	☐				**D_1**		Adjust patient’s head (minor adjustment)
57	**O**	☐	☐	☐		☐	☐						
58	**O**	☐	☐	☐		☐	☐						
59	**O**	☐	☐	☐		☐	☐						
60 (12:00)	**O**	☐	☐	☐		☐	☐						
1	**O**	☐	☐	☐		☐	☐						
2	**O**	☐	☐	☐		☐	☐						
3	**O**	☐	☐	☐		☐	☐						
4	**O**	☐	☐	☐		☐	☐						
5	**O**	☐	☐	☐		☐	☐						
6	**O**	☐	☐	☐		☐	☐						

7	**O**	□	□	□		□	□						
8	**O**	□	□	□		□	□						
9	**O**	□	□	□		□	□						
10	**O**	□	□	□		□	□						
11	**O**	□	□	□		□	□						
12	**O**	□	□	□		□	□						
13	**O**	□	□	□		□	□						
14	**O**	□	□	□		□	□						
15	**O**	□	□	□		□	□						Surgeon starts sewing
16	**O**	□	□	□		□	□						
17	**O**	□	□	□		□	□						
18	**O**	□	□	□		□	□						
19	**O**	□	□	□		□	□						
20	**O**	□	□	□		□	□						
21	**O**	□	□	□		**O**	**O**						Scrub nurse starts counting the equipment and give the surgeon assist, the scout nurse helps the scrub nurse; the surgeon is still sewing
22	**O**	□	□	□		**O**	**O**						
23	**O**	□	□	□		**O**	**O**						
24	**O**	□	□	□		**O**	**O**						

25	**O**	□	□	□		**O**	**O**						
26	**O**	□	□	□		□	□						
27	**O**	□	□	□		□	□						
28	**O**	□	□	□		□	□						
29	**O**	□	□	□		□	□						
30	**O**	□	□	□		□	□						
31	**O**	□	□	□		□	□						
32	**O**	□	□	□		□	□						
33	**O**	□	□	□		□	□						
34	**O**	□	□	□		□	□						
35	**O**	□	□	□		□	□						
36	**O**	□	□	□		□	□						
37	**O**	□	□	□		**O**	**O**						Nurses start to clean up
	O	□	□	□		**O**	**O**						
38	**O**	□	□	□		**O**	**O**						
	O	□	□	□		**O**	**O**						
39	**O**	□	□	□		**O**	**O**						
40	**O**	□	□	□	→	**O**	**O**		→	→			Wardsman and technician arrived
41	**O**	□	□	□	**O**	**O**	**O**		**O**	**O**			Start to clean up

42	□	□	**O**	**O**	**O**	**O**	**O**		**O**	**O**			Completed the surgery; assistant Anaesthetist remove the oxygen and wake up patient; others are cleaning up
43	□	□	**O**	**O**	**O**	**O**	**O**		**O**	**O**			Remove the cover from patient
44	□	□	**O**	**O**	**O**	**O**	→		**O**	→		②	The scout nurse and one of the wards man go out to do something else, and another wards man is watching and waiting beside the patient; only scrub nurse is doing the clean up. (could reduce some time if there are more people to do the clean up)
45	□	□	**O**	**O**	**O**	**O**			**O**			②	
46	□	□	**O**	**O**	**O**	**O**			**O**			②	
47	□	□	**O**	**O**	**O**	**O**			**O**			②	
48	□	□	**O**	**O**	**O**	**O**			**O**			②	
49	□	□	**O**	**O**	**O**	**O**			**O**			②	
50	□	□	**O**	**O**	**O**	**O**			**O**			②	
51	□	□	**O**	**O**	**O**	**O**			**O**			②	
52	□	□	**O**	**O**	**O**	**O**			**O**			①	Move patient to the ward bed by one wardsman, one scrub nurse, and one Anaesthetist
53	□	□	□	□	**O**	→			□			①	Only technician positioning the patient; scrub nurse left the operating room
54	□	→	□	□	□				□				Assistant surgeon goes out
55	□		□	□	□				□				The patient is still sleeping
56	□		□	□	□				□				

57	□		□	□	□				□				
53	□		□	□	□				□				
54	□		**O**	□	□				□				Anaesthetist tries to wake up the patient
55	□		□	□	□				□				
56	□		□	□	□				□				
57	□		□	□	□				□				Nobody prepares instruments for the next operation up to now. This causes the delay of next operation.
58	□		□	□	□				□				
59	□		□	□	□				□				
60 (13:00)	□		→	**O**	**O**				□				Patient wakes up; the Anaesthetist moves the oxygen; Anaesthetist goes out
1	□			**O**	**O**				**O**				Wardsman, assistant Anaesthetist , and scrub nurse prepare to transport the patient
2					→				→	→			Transport to recovery

Appendix 4: Observation Flow sheet—surgery case B

Start Time **8 : 26**	Surgeon	Assistant/Junior Surgeon	Anaesthetist	Assistant Anaesthetist	Technician	Scrub nurse	Scout nurse 1	Scout nurse 2	Wards man 1	Wards man 2	Type of Delay	Type of operation	*Description*
Minute		→	→	→	→				→				Move the patient into the OR
27				**O**	**O**				**O**	**O**			Wardsmen along with Anaesthetists and Technician moved patient to the bed which is inside the OR
28	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			Anaesthetist and Assistant Anaesthetist are supplying Oxygen to the patient. Technician and wardsmen are covering patient’s body with sheet. Meanwhile, scrub nurse is preparing equipment for surgeons. Other two scout nurses are helping scrub nurse preparing
29	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			
30	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			

31	□	□	O	O	O	□	□	□	O	O			Nurses completed preparation; others are still supplying oxygen to the patient. Because this is the first operation, then the nurses were starting to prepare before patient arrived in operating theatre.
32	□	□	O	O	O	O	O	O	O	O			
33	□	□	O	O	O	O	O	O	O	O			
34	□	□	O	O	O	O	O	O	O	O			
35	O	O	O	O	O	O	□	□	O	O			The Anaesthetist also finished supplying oxygen to the patient. And covered the sheet with surgeons, technician and wards man.
36	O	O	O	O	O	O	□	□	O	O			
37	O	O	□	□	→	O	□	□	→	→		①	Surgeon starts to operate with the assistance of scrub nurse; technician, wardsmen walk out of the OR; two scrub nurses are monitoring. The operating table did not measure an adequate height according to the height and preference of surgeon. The height of the surgery table was unsuitable to the surgeon (this might delay the whole operation).
38	O	O	□	□		□	□	□				①	
39	O	O	□	□		O	□	□				②	The scrub nurse did not coordinate her hands very well when she collect and handle the instruments.

40	**O**	**O**	□	□		□	□	□				①	
41	**O**	□	□	□		**O**	□	□				①	
42	**O**	**O**	□	□		**O**	□	□				①	
43	**O**	□	□	□		□	□	□				①	
44	**O**	□	□	□		□	□	□				①	
45	**O**	**O**	□	□		**O**	□	□				①	
46	**O**	**O**	□	□		**O**	□	□				①	
47	→	→	□	□		□	□	□			$\mathbf{D_4}$		The surgeon is changing with assistant surgeon from patient's one side to another.
48	**O**	**O**	□	□		**O**	□	□				①	
49	**O**	**O**	□	□		**O**	□	□				①	
50	**O**	**O**	**O**	**O**		□	□	□				②	The scrub nurse did not coordinate her hands very well when she collected and handled the instruments.
51	**O**	**O**	**O**	**O**		□	□	□				①	
52	**D**	**D**	□	□		□	→	→			$\mathbf{D_0}$		Scout nurses seeking the missing instruments from sterile stock room
53	**D**	**D**	□	□		□	→	→			$\mathbf{D_0}$		
54	**D**	**D**	□	□		□	→	→			$\mathbf{D_2}$		Scout nurse search and give the instrument to surgeon
55	**O**	**O**	□	□		**O**	□	□				①	

56	**O**	**O**	□	□		**O**	□	□				②	The scrub nurse did not coordinate her hands very well when she collect and handle the instruments.
57	**O**	**O**	□	□		□	□	□				①	
58	**O**	**O**	□	□		□	□	□				①	
59	**O**	**O**	□	□		□	□	□				①	
60 (9:00)	**D**	**D**	□	□		□	→	→			$\mathbf{D_0}$		Scout nurses search the missing instruments from sterile stock room
1	**D**	**D**	□	□		□	→	→			$\mathbf{D_0}$		
2	**D**	**D**	□	□		□	→	→			$\mathbf{D_0}$		
3	**D**	**D**	□	□		□	→	→			$\mathbf{D_4}$		Searching + Scout nurse give the instrument to surgeon
4	**O**	**O**	□	□		□	□	□				①	
5	**O**	**O**	□	□		□	□	□				①	
6	**O**	**O**	□	□		□	□	□				①	
7	**O**	**O**	□	□		□	□	□				①	
8	**O**	**O**	□	□		**O**	□	□				②	The scrub nurse did not coordinate her hands very well when she collect and handle the instruments.
9	**O**	□	□	□		□	□	□				①	
10	**O**	□	□	□		□	□	□				①	
11	**O**	□	□	□		□	□	□				①	

12	**O**	□	□	□		□	□	□				①	
13	**O**	□	□	□		**O**	□	□				①	
14	**D**	**D**	□	□		□	→	□			D_0		Scrub nurse brought unsuitable instruments and asked one of the scout nurses to bring the right one.
15	**D**	**D**	□	□		□	→	□			D_4		Scout nurse brought the right instrument to scrub nurse, then give to surgeon
16	**O**	□	□	□		□	□	□				①	
17	**O**	□	□	□		□	□	□				①	
18	**O**	□	□	□		□	□	□				①	
19	**O**	□	□	□		□	□	□				①	
20	**O**	**O**	□	□		□	□	□				①	
21	**O**	**O**	□	□		□	□	□				①	
22	**O**	**O**	□	□		□	□	□				①	
23	**O**	**O**	□	□		□	□	□				①	
24	**O**	**O**	□	□		□	□	□				①	
25	**D**	**D**	□	□		□	□	□			D_0		Surgeon searches for the instruments from the drape area; because the instruments are scattered randomly.
26	**D**	**D**	□	□		**O**	□	□			D_0		
27	**O**	**O**	□	□		**O**	□	□			D_2		
28	**O**	**O**	□	□		□	□	□				①	

	O	**O**	□	□		□	□	□				①	
29	**O**	**O**	□	□		□	□	□				①	
30	**O**	**O**	□	□		□	□	□				①	
31	**O**	□	□	□		□	□	□				①	
32	**O**	□	□	□		□	□	□				①	
33	**O**	□	□	□		□	□	□				①	
34	**O**	**O**	□	□		**O**	□	□				②	The scrub nurse did not coordinate her hands very well when she collects and handles the instruments.
35	**O**	**O**	□	□		□	□	□				①	
36	**O**	**O**	□	□		**O**	□	□				①	
37	**D**	**D**	□	□		□	□	□			$\mathbf{D_0}$		Surgeon search for the instruments from the drop area. Because the instruments are scattered randomly.
38	**O**	**O**	□	□		□	□	□				①	
39	**O**	**O**	□	□		□	□	□				①	
40	**O**	**O**	□	□		□	□	□				①	
41	**D**	**D**	□	□		□	→	→			$\mathbf{D_0}$		Scout nurses search the missing instruments from sterile stock room
42	**D**	**D**	□	□		□	→	→			$\mathbf{D_3}$		Scout nurse gives the instrument to surgeon

43	O	□	□	□		□	□	□				①	
44	O	□	□	□		O	□	□				①	
45	O	□	□	□		□	→	□				①	Scout nurse goes outside
46	O	□	□	□		□		□				①	
47	O	□	□	□		□		□				①	
48	D	D	□	□		□		□			D_0		Surgeon search for the instruments from the drop area. Because the instruments are scattered randomly.
49	D	D	□	□		O		□			D_0		
50	D	D	□	□		□					D_3		Scout nurse gives the instrument to surgeon
51	O	□	□	□		O		O				②	Scrub nurse is counting the equipments and used sponges give the surgeon assist and did not coordinate her hands very well when she collects and handles the instruments. The scout nurse helps the scrub nurse; the surgeon is still operating.
52	O	□	□	□		O		O				①	
53	O	O	□	□		□	→	□				①	Scout nurse returns
54	O	O	□	□		□	□	□				①	
55	O	O	□	□		□	□	□				①	
56	O	O	□	□		O	□	□				②	The nurse was not coordinated her hands very well when she collect and handle the instruments.

57	O	O	□	□		□	□	□				①	
58	O	O	□	□		□	□	□				①	
59	O	O	□	□		□	□	□				①	
60 (10:00)	O	O	□	□		□	□	□				①	
1	O	O	□	□		□	□	□				①	
2	O	O	□	□		□	□	□				①	
3	O	□	□	□		O	□	O				①	Scrub nurse is counting the equipment and used sponges again.
4	O	□	□	□		O	□	O				①	
5	O	□	□	□		□	□	□				①	
6	O	□	□	□		□	□	□				①	
7	O	O	□	□		□	□	□				①	
8	O	O	□	□		□	□	□				①	
9	O	□	□	□		O	□	□				①	Scrub nurse assist surgeon
10	O	□	□	□		□	□	□				①	
11	O	O	□	□		O	□	□				①	
12	O	O	□	□		□	□	□				①	
13	O	O	□	□		□	□	□				①	
14	O	O	□	□		□	□	□				①	

15	**D**	**D**	□	□		□	→	□			**D_0**		Scout nurse searches for the missing instruments from sterile stock room
16	**D**	**D**	□	□		□	→	□			**D_0**		
17	**D**	**D**	□	□		□	→	□			**D_3**		Give to scrub nurse
18	**O**	**O**	□	□		□	□	□				①	
19	**O**	**O**	□	□		□	□	□				①	
20	**O**	**O**	□	□		**O**	□	□				①	Scrub nurse is counting the equipment and used sponges again
21	**O**	**O**	□	□		**O**	□	□				①	
22	**O**	**O**	□	□		□	□	□				①	
23	**O**	**O**	□	□		□	□	□				①	
24	**O**	**O**	□	□		□	□	□				①	Surgeon starts sewing
25	**O**	**O**	□	□		**O**	□	□				①	
26	**O**	□	□	□		**O**	□	□				①	
27	**O**	□	□	□		**O**	□	□				②	The nurse did not coordinate her hands very well when she collected and handle the instruments.
28	**O**	□	□	□		□	□	□				①	
29	**O**	□	□	□		□	□	□				①	
30	**O**	**O**	□	□		□	□	□				①	
31	**O**	□	□	□		**O**	□	□				①	
32	**O**	□	□	□		□	□	□				①	

33	O	□	□	□		□	□	□				①	
34	O	O	□	□		□	□	□				①	
35	O	□	□	□		O	□	□				①	
36	O	□	□	□		O	□	□				①	
37	O	□	□	□		□	□	□				①	
38	O	□	□	□		O	□	□				①	
39	O	□	□	□		□	□	□				①	
40	O	□	□	□		□	□	□				①	
41	O	□	□	□		□	□	□				①	
42	O	□	□	□		O	□	□				②	The nurse did not coordinate her hands very well when she collects and handles the instruments.
43	O	□	□	□		□	□	□				①	
44	O	□	□	□		□	□	□				①	
45	O	□	□	□		O	□	□				①	
46	O	□	□	□		O	O	O				①	Nurses start to clean up
47	O	□	□	□		O	O	O				①	
48	O	□	□	□		O	O	O				①	
49	O	□	□	□		O	O	O				①	
50	O	□	□	□		O	O	O				①	
51	O	□	□	□	→	O	O	O	→	→		①	Wardsman and technician arrive
52	O	□	□	□	O	O	O	O	O	O		①	Start to clean up

53	**O**	□	□	□	**O**	**O**	**O**	**O**	**O**	**O**			Completed the surgery; assistant Anaesthetist remove the oxygen and wake up patient; others are cleaning up
54	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			Remove the cover from patient
55	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**			
56	**O**	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**			Surgeon is entering data into computer
57	**O**	□	□	**O**	**O**	□	□	**O**	**O**	**O**			
58	**O**	□	□	**O**	**O**	**O**	**O**	**O**	**O**	**O**			Move patient to the ward bed
59	□	□	□	□	**O**	**O**	**O**	**O**	**O**	**O**			
60 (11:00)	□	→	□	□	**O**	**O**	**O**	**O**	**O**	**O**			Assistant surgeon goes out
1	□		□	□	**O**	**O**	**O**	**O**	**O**	**O**			
2	□		□	□	**O**	**O**	**O**	**O**	**O**	**O**			
3	□		□	□	**O**	□	□	**O**	**O**	**O**			
4	□		□	□	→	□	□	**O**	**O**	**O**			Scrub nurse left the operating room
5	□		□	□		□	□	**O**	**O**	**O**			
6	□		□	□		□	□	**O**	**O**	**O**			The patient wakes up
7	□		**O**	**O**		□	□	**O**	**O**	**O**			
8	□		→	→		□	□	→	→	→			Transport to recovery area

Appendix 5: Surgery case studies

Surgery case 1: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 7:46 am
- Patient arrive to AR at: 8:01 am
- Patient be moved to OR at: 8:46 am
- OT session end – Patient out: 9:11am
- Total session time: 36 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	3	100%	0
①	5	20%	1
②	2	40%	0.8
③	0	60%	0
④	1	80%	0.8
D_0	21	100%	21
D_1	0	80%	0
D_2	2	60%	1.2
D_3	2	40%	0.8
D_4	0	20%	0
Total	**36**		**25.6**
% Preventable delay = (total preventable/ time surgery time) %			**71.11% of the total surgery time**

Surgery case 2: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 8:27 am
- Patient arrive to AR at: 8:54 am
- Patient be moved to OR at: 9:18 am
- OT session end – Patient out: 10:09am
- Total session time: 51 minutes

Descriptor	**Units**	**Adjustment factor**	**Total preventable delay**
⓪	10	100%	0
①	11	20%	2.2
②	3	40%	1.2
③	0	60%	0
④	14	80%	11.2
$\mathbf{D_0}$	9	100%	9
$\mathbf{D_1}$	1	80%	0.8
$\mathbf{D_2}$	0	60%	0
$\mathbf{D_3}$	1	40%	0.4
$\mathbf{D_4}$	1	20%	0.2
Total	**51**		**25**
% Preventable delay = (total preventable/ time surgery time) %			**49.01% of the total surgery time**

Surgery case 3: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 10:30 am
- Patient Arrival to Pre-operative area: 11:43am
- Patient arrive to AR at: 12:09 pm
- Patient be moved to OR at: 12:45pm
- OT session end – Patient out: 13:56pm
- Total session time: 107 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	64	100%	0
①	4	20%	0.8
②	6	40%	2.4
③	6	60%	3.6
④	0	80%	0
D_0	13	100%	13
D_1	3	80%	2.4
D_2	5	60%	3
D_3	5	40%	2
D_4	1	20%	0.2
Total	**107**		**27.4**
% Preventable delay = (total preventable/ time surgery time) %			**25.61% of the total surgery time**

Surgery case 4: Statistics

- Patient arrival time to theatre admission (reception): 10:30 am
- Patient Arrival to Pre-operative area: 11:27am
- Patient arrive to AR at: 11:32 am
- Patient be moved to OR at: 12:08pm
- OT session end – Patient out: 13:06pm
- Total session time: 58 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	21	100%	0
①	12	20%	2.4
②	4	40%	1.6
③	3	60%	1.8
④	6	80%	4.8
D_0	7	100%	7
D_1	1	80%	0.8
D_2	4	60%	2.4
D_3	0	40%	0
D_4	0	20%	0
Total	**58**		**20.8**
% Preventable delay = (total preventable/ time surgery time) %			**35.86% of the total surgery time**

Surgery case 5: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 8:34am
- Patient arrive to AR at: 8:41 am
- Patient be moved to OR at: 9:13am
- OT session end – Patient out: 11:03am
- Total session time: 110 minutes

Descriptor	**Units**	**Adjustment factor**	**Total preventable delay**
⓪	58	100%	0
①	11	20%	2.2
②	3	40%	1.2
③	4	60%	2.4
④	1	80%	0.8
$\mathbf{D_0}$	11	100%	11
$\mathbf{D_1}$	2	80%	1.6
$\mathbf{D_2}$	0	60%	0
$\mathbf{D_3}$	4	40%	1.6
$\mathbf{D_4}$	7	20%	1.4
Total	**110**		**22.2**
% Preventable delay = (total preventable/ time surgery time) %			**20.18% of the total surgery time**

Surgery case 6: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 10:30 am
- Patient Arrival to Pre-operative area: 15:15pm
- Patient arrive to AR at: 15:21 pm
- Patient be moved to OR at: 16:15pm
- OT session end – Patient out: 16:40pm
- Total session time: 25minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	91	100%	0
①	7	20%	1.4
②	1	40%	0.4
③	0	60%	0
④	0	80%	0
D_0	5	100%	5
D_1	4	80%	3.2
D_2	0	60%	0
D_3	0	40%	0
D_4	1	20%	0.2
Total	**25**		**10.2**
% Preventable delay = (total preventable/ time surgery time) %			**40.8% of the total surgery time**

Surgery case 7: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45am
- Patient Arrival to Pre-operative area: 7:38am
- Patient arrive to AR at: 8:00 am
- Patient be moved to OR at: 8:18am
- OT session end – Patient out: 9:38am
- Total session time: 80 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	56	100%	0
①	5	20%	1
②	6	40%	2.4
③	1	60%	0.6
④	4	80%	3.2
D_0	4	100%	4
D_1	0	80%	0
D_2	3	60%	1.8
D_3	0	40%	0
D_4	1	20%	0.2
Total	**80**		**13.2**
% Preventable delay = (total preventable/ time surgery time) %			**16.5% of the total surgery time**

Surgery case 8: <u>**Statistics**</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 9:18am
- Patient arrive to AR at: 9:29 am
- Patient be moved to OR at: 10:47am
- OT session end – Patient out: 11:51am
- Total session time: 64 minutes

Descriptor	**Units**	**Adjustment factor**	**Total preventable delay**
⓪	34	100%	0
①	4	20%	0.8
②	7	40%	2.8
③	0	60%	0
④	3	80%	2.4
$\mathbf{D_0}$	7	100%	7
$\mathbf{D_1}$	1	80%	0.8
$\mathbf{D_2}$	0	60%	0
$\mathbf{D_3}$	5	40%	2
$\mathbf{D_4}$	3	20%	0.6
Total	**64**		**16.4**
% Preventable delay = (total preventable/ time surgery time) %			**25.62% of the total surgery time**

Surgery case 9: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 7:46 am
- Patient arrive to AR at: 8:08 am
- Patient be moved to OR at: 8:26 am
- OT session end – Patient out: 11:08am
- Total session time: 162 minutes

Descriptor	**Units**	**Adjustment factor**	**Total preventable delay**
⓪	25	100%	0
①	106	20%	21.2
②	9	40%	3.6
③	0	60%	0
④	0	80%	0
$\mathbf{D_0}$	14	100%	14
$\mathbf{D_1}$	0	80%	0
$\mathbf{D_2}$	2	60%	1.2
$\mathbf{D_3}$	3	40%	1.2
$\mathbf{D_4}$	3	20%	0.6
Total	**162**		**41.8**
% Preventable delay = (total preventable/ time surgery time) %			**25.80% of the total surgery time**

Surgery case 10: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 10:24am
- Patient arrive to AR at: 10:27 am
- Patient be moved to OR at: 10:57am
- OT session end – Patient out: 11:43am
- Total session time: 46 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	21	100%	0
①	3	20%	0.6
②	6	40%	2.4
③	3	60%	1.8
④	2	80%	1.6
D_0	6	100%	6
D_1	3	80%	2.4
D_2	0	60%	0
D_3	1	40%	0.4
D_4	1	20%	0.2
Total	**46**		**10**
% Preventable delay = (total preventable/ time surgery time) %			**21.74% of the total surgery time**

Surgery case 11: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 10:30 am
- Patient Arrival to Pre-operative area: 12:27pm
- Patient arrive to AR at: 12:38 pm
- Patient be moved to OR at: 12:40 pm
- OT session end – Patient out: 13:09 pm
- Total session time: 29 minutes

Descriptor	**Units**	**Adjustment factor**	**Total preventable delay**
⓪	21	100%	0
①	5	20%	1
②	0	40%	0
③	6	60%	3.6
④	2	80%	2
$\mathbf{D_0}$	2	100%	2
$\mathbf{D_1}$	0	80%	0
$\mathbf{D_2}$	3	60%	1.8
$\mathbf{D_3}$	0	40%	0
$\mathbf{D_4}$	3	20%	0.6
Total	**29**		**11**
% Preventable delay = (total preventable/ time surgery time) %			**37.93% of the total surgery time**

Surgery case12: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 10:30 am
- Patient Arrival to Pre-operative area: 12:18 pm
- Patient arrive to AR at: 12:40 pm
- Patient be moved to OR at: 12:46 pm
- OT session end – Patient out: 13:29 pm
- Total session time: 43 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	16	100%	0
①	3	20%	0.6
②	1	40%	0.4
③	0	60%	0
④	3	80%	2.4
D_0	3	100%	3
D_1	1	80%	0.8
D_2	3	60%	1.8
D_3	1	40%	0.4
D_4	0	20%	0
Total	**43**		**9.4**
% Preventable delay = (total preventable/ time surgery time) %			**21.86% of the total surgery time**

Surgery case 13: Statistics

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 9:06 am
- Patient arrive to AR at: 9:36 am
- Patient be moved to OR at: 9:44 am
- OT session end – Patient out: 10:39 am
- Total session time: 55 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	26	100%	0
①	11	20%	2.2
②	5	40%	2
③	4	60%	2.4
④	1	80%	0.8
D_0	3	100%	3
D_1	0	80%	0
D_2	0	60%	0
D_3	4	40%	1.6
D_4	1	20%	0.2
Total	**55**		**10.4**
% Preventable delay = (total preventable/ time surgery time) %			**18.91% of the total surgery time**

Surgery case 14: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 9:09am
- Patient arrive to AR at: 10:10 am
- Patient be moved to OR at: 10:42am
- OT session end – Patient out: 12:27pm
- Total session time: 105 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	64	100%	0
①	12	20%	2.4
②	0	40%	0
③	6	60%	3.6
④	3	80%	2.4
D_0	6	100%	6
D_1	2	80%	1.6
D_2	0	60%	0
D_3	5	40%	2
D_4	7	20%	1.4
Total	**105**		**19.4**
% Preventable delay = (total preventable/ time surgery time) %			**18.47% of the total surgery time**

Surgery case 15: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 8:57am
- Patient arrive to AR at: 9:15 am
- Patient be moved to OR at: 10:08am
- OT session end – Patient out: 10:25pm
- Total session time: 17 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	5	100%	0
①	2	20%	0.4
②	1	40%	0.4
③	1	60%	0.6
④	1	80%	0.8
D_0	5	100%	5
D_1	1	80%	0.8
D_2	0	60%	0
D_3	0	40%	0
D_4	1	20%	0.2
Total	**17**		**8.2**
% Preventable delay = (total preventable/ time surgery time) %			**48.24% of the total surgery time**

Surgery case 16: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 8:51am
- Patient arrive to AR at: 9:16 am
- Patient be moved to OR at: 9:31am
- OT session end – Patient out: 9:54pm
- Total session time: 23 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	14	100%	0
①	3	20%	0.6
②	0	40%	0
③	2	60%	1.2
④	0	80%	0
D_0	1	100%	1
D_1	0	80%	0
D_2	2	60%	1.2
D_3	0	40%	0
D_4	1	20%	0.2
Total	**23**		**4.2**
% Preventable delay = (total preventable/ time surgery time) %			**18.26% of the total surgery time**

Surgery case 17: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 10:30 am
- Patient Arrival to Pre-operative area: 13:20 pm
- Patient arrive to AR at: 13:58 pm
- Patient be moved to OR at: 14:00 pm
- OT session end – Patient out: 14:46 pm
- Total session time: 46 minutes

Descriptor	**Units**	**Adjustment factor**	**Total preventable delay**
⓪	32	100%	0
①	4	20%	0.8
②	1	40%	0.4
③	2	60%	1.2
④	0	80%	0
$\mathbf{D_0}$	3	100%	3
$\mathbf{D_1}$	0	80%	0
$\mathbf{D_2}$	2	60%	1.2
$\mathbf{D_3}$	1	40%	0.4
$\mathbf{D_4}$	1	20%	0.2
Total	**46**		**7.2**
% Preventable delay = (total preventable/ time surgery time) %			**15.65% of the total surgery time**

Surgery case 18: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 10:25am
- Patient arrive to AR at: 10:32 am
- Patient be moved to OR at: 11:15am
- OT session end – Patient out: 12:26pm
- Total session time: 71 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	41	100%	0
①	11	20%	2.2
②	2	40%	0.8
③	2	60%	1.2
④	0	80%	0
D_0	6	100%	6
D_1	3	80%	2.4
D_2	5	60%	3
D_3	1	40%	0.4
D_4	0	20%	0
Total	**71**		**10.6**
% Preventable delay = (total preventable/ time surgery time) %			**14.92% of the total surgery time**

Surgery case 19: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 8:02am
- Patient arrive to AR at: 8:15 am
- Patient be moved to OR at: 8:42am
- OT session end – Patient out: 10:56am
- Total session time: 134 minutes (NOTES: The patient should be move to OR before 8: 30)

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	91	100%	0
①	9	20%	1.8
②	1	40%	0.4
③	4	60%	2.4
④	4	80%	3.2
D_0	19	100%	19
D_1	0	80%	0
D_2	5	60%	3
D_3	0	40%	0
D_4	1	20%	0.2
Total	**134**		**30**
% Preventable delay = (total preventable/ time surgery time) %			**22.38% of the total surgery time**

Surgery case 20: Statistics

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 7:55 am
- Patient arrive to AR at: 8:46 am
- Patient be moved to OR at: 8:58 am
- OT session end – Patient out: 9:30 am
- Total session time: 32 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	16	100%	0
①	5	20%	1
②	1	40%	0.4
③	2	60%	1.2
④	1	80%	0.8
D_0	3	100%	3
D_1	1	80%	0.8
D_2	2	60%	1.2
D_3	0	40%	0
D_4	1	20%	0.2
Total	**32**		**8.6**
% Preventable delay = (total preventable/ time surgery time) %			**26.87% of the total surgery time**

Surgery case 21: Statistics

- Patient arrival time to theatre admission (reception): 6:45 am
- Patient Arrival to Pre-operative area: 8:23 am
- Patient arrive to AR at: 9:28 am
- Patient be moved to OR at: 9:48 am
- OT session end – Patient out: 13:02pm
- Total session time: 192 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	125	100%	0
①	13	20%	2.6
②	13	40%	2.6
③	1	60%	0.6
④	1	80%	0.6
D_0	22	100%	22
D_1	7	80%	5.6
D_2	4	60%	2.4
D_3	2	40%	0.8
D_4	4	20%	0.8
Total	**192**		**38**
% Preventable delay = (total preventable/ time surgery time) %			**19.79% of the total surgery time**

Surgery case 22: <u>Statistics</u>

- Patient arrival time to theatre admission (reception): 10:30 am
- Patient Arrival to Pre-operative area: 13:07
- Patient arrive to AR at: 13:42 pm
- Patient be moved to OR at: 13:50 pm
- OT session end – Patient out: 14:00 pm
- Total session time: 10 minutes

Descriptor	Units	Adjustment factor	Total preventable delay
⓪	4	100%	0
①	3	20%	0.6
②	1	40%	0.4
③	0	60%	0
④	0	80%	0
D_0	0	100%	0
D_1	1	80%	0.8
D_2	0	60%	0
D_3	0	40%	0
D_4	1	20%	0.2
Total	**10**		**2**
% Preventable delay = (total preventable/ time surgery time) %			**20% of the total surgery time**

Appendix 6: Ethic Clearance

Queensland Government

Queensland **Health**

Enquiries to:	Coordinator HREC & RS
Telephone:	(61 7) 4699 8316
Facsimile:	(61 7) 4699 8940
Our Ref:	TDDHSD HREC2007/027
E-mail:	TWB_Research_and_Ethics@health.qld.gov.au

Dr Latif Al-Hakim
Faculty of Business
University of Southern Queensland
Unit 6
779 Ruthven Street
TOOWOOMBA QLD 4350

Dear Dr Al-Hakim

Re: TDDHSD HREC 2007/027
"Adapted lean thinking for healthcare"

At a meeting of the Toowoomba & Darling Downs Health Service District Human Research Ethics Committee held on 12/06/2008, the Committee reviewed the above Protocol. The Toowoomba & Darling Downs Health Service District Human Research Ethics Committee is duly constituted, and operates and complies with the National Health and Medical Research Council's 'National Statement on Ethical Conduct in Research Involving Humans and Supplementary Notes, 1999'.

It is advised that on the recommendation of the Human Research Ethics Committee, the District Manager, Toowoomba & Darling Downs Health Services District has approved your request for ethical approval of the following:

- NEAF Application Form: **"Adapted lean thinking for healthcare"** version 1.1 completion date 9/04/2008
- Information and Consent Form for Meeting Participants
- Letter of Support from Executive Director of Toowoomba Hospital

During the conduct of the study you are required to adhere to the following conditions:

- In the first instance please sign, date and return a copy of the back page of this letter, and also complete the enclosed Commencement Form (yellow) and return to this office when the study commences.
- All investigations must be carried out according to the "Declaration of Helsinki 2000" as subsequently modified and the latest statement by the National Health and Medical Research

Office	Postal	Phone	Fax
Queensland Health Toowoomba & Darling DownsHealth Service District Pechey Street Toowoomba 4350	Private Mail Bag 2 Toowoomba 4350	(61 7) 4616 6000	(61 7) 4616 6170

Council on Human Experiments and on Scientific Practice. Should a copy of the 'Declaration of Helsinki 2000' as subsequently modified be required, please request a copy from the Coordinator, Human Research Ethics Committee.

- Attachment I is a letter listing some matters specified by the National Health and Medical Research Council to which you as the research worker must adhere.
- Attachment II gives the Committee composition with specialty and affiliation with hospital.
- You are required to provide a report on any pilot study and the outcome of the study at the completion of the trial or annually if the trial continues for more than 12 months.
- If any subsequent change/amendment is made to the protocol it will be necessary for you to obtain approval from the Human Research Ethics Committee. The amended documents must be accompanied by a letter, signed by the Principal investigator, providing a brief description of the changes, the rationale for them and their implications for the ongoing conduct of the study. All amended documents must contain revised version numbers, version dates and page numbers. Changes must be highlighted using Microsoft Word "Track Changes" or similar. Please contact the HREC Coordinator if assistance is required.
- Serious Adverse Events must be notified to the Committee as soon as possible. In addition the Investigator must provide a summary of the adverse events, in the specified format, including a comment as to suspected causality and whether changes are required to the Patient Information and Consent Form. In the case of Serious Adverse Events occurring at the local site, a full report is required from the Principal Investigator, including duration of treatment and outcome of event.
- If the results of your protocol are to be published, an appropriate acknowledgment of the Hospital should be contained in the article. Copies of all publications resulting from the study should be submitted to the Human Research Ethics Committee.
- Please ensure that a copy of any publication that results from this protocol is also forwarded to the Hospital Medical Library for future reference.
- The Hospital administration and the Human Research Ethics Committee may inquire into the conduct of any research or purported research, whether approved or not and regardless of the source of funding, being conducted on hospital premises or claiming any association with the Hospital; or which the Committee has approved if conducted outside Toowoomba Health Service District. This may include consultation with the Principal Investigator and/or a visit to the research site by a member of the HREC and/or Coordinator of the HREC.

Should you have any problems, please liaise directly with the Chairman of the Human Research Ethics Committee early in your program.

We wish you every success in undertaking this research.

Yours faithfully

G. Beal

for Dr Scott Kitchener
Chair, Human Research Ethics Committee
3/07/2008
For District Manager, ***Toowoomba & Darling Downs Health Service District***