Lean Six Sigma to Reduce Pharmacy Medication Errors in Thai Hospitals: an Action Research Study

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ABSTRACT

Hospital medication errors are costly and contribute to patient mortality, morbidity and decreased health care quality. Although healthcare organizations have endeavoured to reduce medication errors by using several approaches, the errors remained, returned or could not be resolved. The use of CI methodologies, such as Lean Six Sigma, can enable healthcare practitioners to ascertain the problems in the medication process and identify and eliminate the root cause of such problems. However, the existing literature does not address the need for an LSS roadmap in reducing medication errors; therefore, healthcare practitioners do not have an LSS roadmap to follow to reduce medication errors. This study aims to develop an LSS implementation and sustainability roadmap that can guide healthcare practitioners in the implementation of LSS to reduce medication errors.

A systematic review was conducted to understand the benefits, challenges, and success factors of LSS implementation in reducing medication errors in a global context. The action research methodology was used to illustrate the employment of Lean Six Sigma through collaboration between the researcher and participants in an inpatient pharmacy of two public hospitals in Thailand. This study was carried out through action research based on the following key phases: identification of problems, reflection, planning action, taking action, evaluation, reflection and specify lessons learnt.

The key finding of the systematic literature review revealed that Lean Six Sigma can be very useful on reducing medication errros in a hospital setting and improving patient care. The action research findings clearly show that Lean Six Sigma application improved the inpatient pharmacy dispensing process and contributed to reduced dispensing errors and enhanced patient safety. This is the first study that has developed an LSS roadmap which healthcare practitioners can follow to reduce medication errors using, LSS methodology and, and to sustain LSS in their organizations. This study provides a greater awareness for senior managers and medical directors in hospitals about the role of LSS and its associated tools and techniques in tackling medication errors. Future research can apply the roadmap in other hospitals to ensure its practical validity and enhance the application of LSS in the healthcare setting.

DEDICATION

To my beloved parents 'Niwat and Sayjai Trakulsunti'

Your support drives me to be successful in life

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DECLARATION STATEMENT

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This thesis contains one or more multi-author published works. In accordance with Regulation 6 (9.1.2) I hereby declare that the contributions of each author to these publications is as follows:

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Author 2	Conceived the ideas of the study, provided revisions to manuscript
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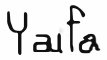
Signature:	
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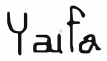
Signature:	
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Trakulsunti, Y. and Antony, J. (2018) 'Can Lean Six Sigma be used to reduce medication errors in the health- care sector ?' *Leadership in Health Services*, 31(4), pp. 426–433.

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CHAPTER 1 – INTRODUCTION

1.1 Introduction

Patient safety is an important goal of healthcare quality (WHO, 2017b). It is a necessary dimension for both healthcare providers and patients (Limpanyalert, 2018). Patients should receive correct dosages and concentrations of prescribed medication on time throughout the treatment regimen. Recent studies identify medication errors as a global issue, with prescription errors in the UK reportedly affecting 12% of all primary care patients and 38% of those aged 75 years and above (WHO, 2016). Annually, in the USA, 8,000 people on average die as a result of medication errors (Tariq and Scherbak, 2019) with approximately 1.3 million people being injured because of such error (U.S. Food and Drug Administration, 2016). In Thailand, the rate of hospital medication errors has not been estimated due to a lack of national data (Chumchit *et al*., 2015). However, the top three causes of adverse events (AEs) which were surveyed by the Ministry of Public Health were medical errors, communication issues and the care process (Limpanyalert, 2018).

A report based on the USA findings published by the Institute of Medicine (IOM), *To Err Is Human: Building a Safer Health System*, highlights the incidence of preventable adverse drug events resulting from medication errors, implicating medication errors in an estimated one in every 131 outpatient deaths, one in 854 inpatient deaths and 7000 deaths per annum (Kohn *et al*., 2000). The annual financial cost of medication errors worldwide is estimated at $40 billion (WHO, 2017a). Reducing medication errors and the harm caused by such errors is a critical issue internationally that offers clear socioeconomic benefits (Crane and Crane, 2006). Hence, there is an urgent need to address healthcare problems caused by medication errors at a global level. Continuous improvement methodologies such as Lean and Six Sigma can be very useful in improving medication process in a hospital setting.

Several studies have identified Lean and Six Sigma as two of the most widely adopted and well-documented process improvement methodologies in manufacturing across all highly reliable and safe industries (e.g. manufacturing, aviation, US Navy) (Dumitrescu and Dumitrache, 2011). Lean originated from the Japanese automobile industry, principally known as the Toyota Production System (Womack *et al*., 1990). Lean philosophy focuses on the elimination of waste and non-value added activities from work processes, thus increasing the work speed and reducing operational costs.

The concept of Six Sigma was introduced by Bill Smith, an engineer at Motorola in the mid-1980s (Antony, 2006). Six Sigma is a process-focused and data-driven methodology (Elbireer *et al*., 2013; Gijo *et al*., 2013). Hospitals have faced several difficulties when deploying Six Sigma (Snee, 2010); however many leading healthcare organizations have found Six Sigma to reduce Emergency Room (ER) cycle time, increase bed availability and reduce medication errors (Gijo *et al*., 2013). Importantly, the integration of Lean and Six Sigma as Lean Six Sigma (LSS) can contribute to better outcomes rather than those gained from the implementation of each methodology individually (Bhat *et al*., 2014; Antony *et al*., 2019b).

Previous studies have shown that the implementation of LSS in the healthcare sector, particularly in hospitals, has resulted in notable improvements in the quality of care, patient safety, staff and patient satisfaction, and cost reduction. In recent years, there has been an increasing interest in the use of Lean, Six Sigma and LSS application to reduce medication errors, especially in the developed countries. The use of Lean and Six Sigma tools enables healthcare practitioners to ascertain the problems in the medication process, and then identify and eliminate the cause of such problems. For example, a study in the Netherlands used LSS methodology to reduce medication administration errors, which resulted in a reduction of 50 per cent and therefore decrease in the potential risk of harm (van de Plas *et al.*, 2017). However, research on the subject has been mostly restricted to the implementation of continuous improvement methodology in healthcare for reducing medication errors and the extant literature does not provide an LSS roadmap for healthcare practitioners to follow. Therefore, this research aims to to develop an LSS implementation and sustainability roadmap to be followed by healthcare practitioners to reduce medication errors.

1.2 Rationale for the study

A Medication error is a global public health issue (WHO, 2016). It is a major contribution to poor patient safety outcomes, particularly in low and middle incomes countries that have fewer resources (Harrison *et al*., 2015). In Southeast Asian countries such as Thailand, Vietnam, and Indonesia, public hospitals are underdeveloped due to insufficient resources, finance, and policy support (Gauld *et al*., 2018). The health systems in Southeast Asian countries are struggling to identify and minimize medication errors due to inequitable socioeconomic development, high population density, and shortages of healthcare staff (Chongsuvivatwong *et al*., 2011).

In Thailand, despite several attempts to promote patient safety in hospitals, medication errors remain a serious problem for patient safety mainly due to inadequate hospital quality management systems (Limpanyalert, 2018). Even in those hospitals that are encouraged to employ quality tools (e.g. cause and effect analysis), the tools cannot be used to identify or solve the root cause of the problems in the medication process. Correcting the consequence of medication errors is costly. For example, in 2016, the National Health Security Office paid an average of USD 7,200 per case to 885 patients and/or their families who had suffered from the undesirable consequences of medication practices (National Health Security Office, 2016).

Evidence shows that medication errors lead to patient mortality and morbidity and are a costly problem in hospitals. Failures in the medication process can lead to decreased patient safety, decreased patient satisfaction with the reduced quality of care being provided and distrust of the healthcare sector (Wittich *et al*., 2014). Other patient outcomes resulting from medication errors include psychological and physical suffering (Whittaker *et al*., 2018).

Medication errors can occur at every stage of the medication process (Antony *et al*., 2019b). Given that medication error is causing death and less serious outcomes there is an urgent need to address health problems caused by these errors. A variety of technological interventions are being used to reduce medication errors, including computerised physician order entry (CPOE), automated dispensing cabinets and bar-coding (NR and BMY, 2013). However, the use of technology intervention requires large capital investment and maintenance and may create new types of error. The automated system should be considered as a tool to improve the medication use process rather than a permanent solution to solve problems in that process (American Society of Health-System Pharmacists, 2010). Moreover, previous studies have implemented non-technology approaches, such as using 'tall man letter', to differentiate between the 'look alike sound alike medications' by changing medication labels and promoting staff awareness about good practice on collecting and dispensing medications (Wittich, 2014; Stefanacci and Riddle, 2016). Despite such approaches, the root causes of the problems have remained in the process and have not been resolved.

The use of CI methodologies can enable healthcare practitioners to both ascertain the problems in the medication process and identify and eliminate the root cause of such problems. CI methodologies are widely implemented in every type and size of

organization, from manufacturing to the public sector with the aim of managing the achievement of quality (Brown *et al*., 2008). However, the implementation of CI methodologies is not widely applied in the public sector compared with the private sector (Elias and Davis, 2018). Some of the major challenges identified in the application of CI methodologies in the public sector relate to changing the organization's culture, a lack of customer focus and the tensions between multiple stakeholders demanding different requirements (Fryer *et al*., 2007).

The most popular business strategies for the employment of CI in the manufacturing and service sectors are Lean and Six Sigma (Albiliwi *et al*., 2015). However, the current literature has shown the limitations of LSS application in reducing errors in the medication process, when compared with other healthcare settings such as the emergency department and surgery/operating room. Moreover, the extant literature does not provide an LSS roadmap for healthcare practitioners to follow in order to successfully implement LSS to reduce medication errors and sustain LSS in their organizations. Most of the framework are based on DMAIC methodology (e.g. Yeh *et al*. 2011; Cheng and Chang 2012) which is useful for reducing medication errors; however, these frameworks will never change the culture of the hospitals. Several aspects are omitted such as communicating the need for LSS in hospitals, training regarding the use of LSS tools, training curricula, project selection and the links to the strategic objectives of the hospitals, teamwork, and formulation for the execution of projects, etc.

1.3 Research aim and research questions

The research aims "to develop an LSS implementation and sustainability roadmap to be followed by healthcare practitioners to reduce medication errors". Table 1.1 shows the research questions and methodology which are used to address such questions. There is limited literature that critically reviews Lean and Six Sigma methodologies in the context of medication errors. Only two studies, conducted by Glasgow *et al*. (2010) and Mason *et al.* (2015), have systematically reviewed the application of Lean and Six Sigma in the surgical and acute care settings. Other studies, such as Antony *et al*. (2018b), conducted a systematic review to illustrate the application of Six Sigma methodology to improve the quality of healthcare. Therefore, the first research question entails the systematic review of successful applications of Lean, Six Sigma and LSS interventions that have been aimed at reducing medication errors in hospitals. The review of this literature led to an

understanding of the current status (benefits, challenges, success factors, tools and techniques) of LSS in reducing medication errors.

Most studies of LSS implementation for reduction of medication errors have been carried out in the USA. Asian countries such as Thailand are far behind the USA and no study has been found which included Lean, Six Sigma or LSS to reduce medication errors. Compared with developed countries, the main problem in Thailand is a lack of quality management in hospitals (Chaiyakunapruk *et al*., 2016). Also, there is a lack of awareness of the benefits of LSS in Thai Hospitals as well as inadequate knowledge of the LSS tools (Nonthaleerak and Henry, 2007). Therefore, the second research question aims to understand the benefits, challenges, and success factors of LSS application in the context of Thai hospitals.

Previous studies have shown a lack of understanding in how to select and use LSS to reduce medication errors in each phase of DMAIC methodology. In the define phase, previous studies have not used common tools such as project charter to identify the details of the project (Chan, 2004; Castle *et al*., 2005; Nayar *et al*., 2016) and have not mentioned any tools to be used in order to identify the problems (Benitez *et al*., 2007). In the measure phase, several studies, such as Benitez *et al*. (2007), Yousef and Yousef (2017), and van de Plas *et al*. (2017), have not identified how to collect the medication errors and present them in the control chart. In the analyse phase, the previous studies have used brainstorming to identify the causes of the problems and there has been a lack of tools used to identify the root causes of the problems (Esimai, 2005; Castle *et al*., 2005; Benitez, 2007). In the control phase, there are no studies that have used the control chart to compare the errors before and after the implementation of LSS (Chan 2004; Esimai, 2005; Castle 2005; Nayar *et al*., 2016; Al Kuwaiti, 2016).

The third research question aims at presenting the most important tools and techniques that can be used to reduce medication errors through action research methodology. In the 'taking action' phase, DMAIC methodology was implemented through collaboration between the researcher and participants. Several tools from the LSS toolbox were applied in each phase of the methodology. These tools could be added to the LSS implementation and sustainability roadmap.

Few published papers have proposed a practical implementation of an LSS roadmap in a service context (Nonthaleerak and Henry, 2007). Most of the existing frameworks have used DMAIC methodology as the LSS framework (Yeh *et al*. 2011; Cheng and Chang

2012; Honda *et al.* 2018; Al-Qatawneh *et al.* 2109). The existing literature does not address the need for an LSS roadmap in reducing medication errors; therefore, healthcare practitioners do not have an LSS roadmap to follow to reduce medication errors (Antony and Kumar, 2012). The fourth research question aims to propose an LSS roadmap to guide healthcare practitioners in the implementation of LSS for reducing medication errors. To answer this, the researcher started reviewing the existing literature of Lean, Six Sigma and Lean Six Sigma frameworks/roadmaps in healthcare combined with the action research study being conducted in Hospital A and Hospital B.

Table 1.1 Research questions and methodological approaches

Research Questions	Methodology
Research Question 1: What is the current status (benefits, challenges, success factors) in the use of Lean Six Sigma to reduce medication errors in a global context?	Systematic Literature Review
Research Question 2: What are the benefits, challenges and success factors in the use of Lean Six Sigma to reduce medication errors in Thai Hospitals?	Action Research
Research Question 3: What tools and techniques of Lean and Six Sigma can be utilized to reduce medication errors?	Action Research
Research Question 4: How can a Lean Six Sigma implementation and sustainability roadmap be developed to guide healthcare practitioners in the reduction of medication errors?	Action Research

1.4 Origin of the study

The components of the medication-use process in the inpatient pharmacy are complex and require improvement. The literature reveals that only two studies have used continuous improvement methodology, such as LSS, in the outpatient pharmacy service (Chan, 2004 and Al Kuwaiti, 2016). This demonstrates that there is a lack of research to apply LSS in the inpatient pharmacy setting. Therefore, this is the first study that applies

LSS methodology to improve the medication process and quality of care in the inpatient pharmacy of public hospitals.

The importance of this study is that it illustrates the use and implementation of LSS and, along with its tools and techniques, to reduce medication errors in public hospitals, through collaboration between the researcher and healthcare practitioners. The study offers important insights into the benefits, challenges and critical success factors of LSS employment for reducing medication errors. This study provided an important opportunity to advance understanding of tools and techniques that can be used to reduce medication errors in various phases of LSS methodology.

In addition, this is the first study to use an action research methodology to reduce medication errors in public hospitals. This study contributes to an understanding of how the application of action research in the healthcare sector and how action research methodology can save patients' lives, improve patient safety and increase work satisfaction in the pharmacy service. Previous published studies have focused on reducing errors, but they have not ascertained the views of participants (Esimai, 2005; Benitez *et al*., 2007; Al Kuwaiti, 2016). The use of action research methodology can capture participants' perspectives and evaluate the outcomes of the implementation of LSS.

Moreover, this is the first attempt in the development of an LSS roadmap that healthcare practitioners can follow to reduce medication errors using LSS methodology and sustaining LSS in their organizations.

1.5 Research context: Thailand

1.5.1 Geography, socio-demographic and health status

Thailand, a constitutional monarchy and parliamentary democracy, is located at the centre of Southeast Asia and covers an area of 513120 km^2 (Tangcharoensathien *et al*., 2018). Thailand is bordered by Myanmar, Laos, Cambodia, and Malaysia (Figure 1.1). The current population of Thailand is approximately 70 million people according to the latest estimation of the United Nations (United Nations, 2019). Thailand is becoming an aging society due to low fertility, birth and mortality rates (Tangcharoensathien *et al*., 2018; Chunharas and Boonthamcharoen, 2019). Most Thais are Buddhists (94.5 percent), and the remaining minority religions are Muslim, Christian, and others (National Statistical Office, 2015). Out of the total population, the major ethnic group in Thailand

is Thai (75 percent), and minority groups (25 percent) including hill tribes, Khmers and Mons (World Population Review, 2019). Non-communicable diseases, infectious diseases including malaria and tuberculosis and road traffic injuries have become a public health issue in Thailand (WHO, 2017c). Total expenditure on health represented 4.1% of the gross domestic product, GDP in 2014 (WHO, 2019).

Figure 1.1 Map of Thailand
Source: Tangcharoensathien *et al.* (2018)

1.5.2 Overview of the healthcare system in Thailand

The healthcare system in Thailand operates within the private and public sectors. The majority of healthcare services are provided by the public sector under the Ministry of Public Health (Chaiyakunapruk *et al*., 2016). The responsibilities of the Ministry of Public Health are health promotion, prevention, disease control, treatment and rehabilitation (Tangcharoensathien *et al*., 2018). Public health insurance schemes are classified into three main types: Universal Coverage Scheme (UCS); Civil Servants Medical Benefits Scheme (CSMBS); and Social Health Insurance Scheme (SHI) (Tangcharoensathien *et al*., 2018). The healthcare system has been organized as a multilevel structure to ensure that the services achieve geographical equity and delivery system efficiency (Chaiyakunapruk *et al*., 2016). Structurally, there is at least one Tambon (sub-district) health promotion hospital in each sub-district, one district hospital

at the district level and some general hospitals at the provincial level (WHO, 2017b). Currently, the Thai government aims to control total health expenditure and reduce staff workload at higher levels of healthcare facilities by strengthening primary health care at the community level (Jongudomsuk *et al*., 2015).

Healthcare services in Thailand are provided by both the public and private sectors, and about 90% of public healthcare services are operated under the Ministry of Public Health (Chunharas and Boonthamcharoen, 2019). Public hospitals are classified into: 1) provincial hospitals (regional hospital; general hospitals; community hospital; crown prince hospital; sub-district health promoting hospitals); 2) Non-Ministry of Public Health organizations and 3) University hospitals (Chunharas and Boonthamcharoen, 2019). Healthcare providers under the Ministry of Public Health are classified into: primary health care including health centres; secondary care including community and general hospitals; and tertiary care including general, specialized and regional hospitals (Chunharas and Boonthamcharoen, 2019).

1.5.3 Hospital pharmacy practice

Thai hospital pharmacy services are classified into four categories: outpatient pharmacy, inpatient pharmacy service, drug information service and other services (e.g. chemotherapy, therapeutic drug monitoring, quality management) (Chaiyakunapruk *et al*., 2016). Prior to 1990, drug dispensing and distribution were the main services for outpatients and inpatients departments. Then, the services for inpatient care focused more on clinical pharmacy activities such as ward-rounding, medication reconciliation, and therapeutic drug monitoring after the concept of pharmaceutical care was adopted (Chaiyakunapruk *et al*., 2016). Daily dose distribution system is the most common hospital medication distribution system in Thailand due to staff and financial constraints (Leelasiriwilas and Ngor-suraches, 2005). The details of the medication distribution system of the two hospitals in which this research was conducted are explained in Chapter 4.

In addition, Chaiyakunapruk *et al.* (2016) mentioned that the Thai pharmacy care system has encountered several challenges. The number of pharmacists in hospitals and community pharmacies is insufficient even though a high number of pharmacy students graduate each year. Thai hospital pharmacies have not reached high standards yet due to the limitations of financial and human resources and technology intervention such as pharmacy automation.

1.6 Structure of the thesis

Chapter Two: Literature Review

The chapter explores the current knowledge of Lean, Six Sigma and Lean Six Sigma in healthcare sectors. The chapter reviews the incidences and impact of medication errors. The chapter further presents the systematic review of Lean, Six Sigma and LSS intervention and its tools and techniques to reduce medication errors in hospitals. This review contributes to the identification of research gaps, and further justifies the research questions for the study.

Chapter Three: Research design and methodology

The chapter presents and justifies the choice of the research approaches, methodologies, and methods which are linked to pragmatism. Thereafter, the researcher developed an action research model to be used in the study. Details of data analysis and ethical considerations are presented in the final section of the chapter.

Chapter Four: Action Research Methodology

The chapter presents the details of the key phases of the action research methodology following the action research model developed in Chapter Three. The application of action research in healthcare and its characteristics are discussed. The research settings of both hospitals are further explained. Then the details of how the data were collected in each phase of action research are further described. The final section describes how the research has been carried out rigorously.

Chapter Five: Action Research findings from Hospital A

The chapter presents the key findings from the action research methodology undertaken in the inpatient pharmacy in Hospital A. The findings are presented according to the key phases of the Action Research model developed in Chapter Three. Afterwards, the chapter identifies challenges and critical success factors for LSS employment as perceived by the participants. Finally, reflections and key lessons learnt by the researcher regarding the research process throughout all phases of the action research are presented.

Chapter Six: Action Research findings from Hospital B

The chapter presents the key findings from action research undertaken in the inpatient pharmacy in Hospital B. The key findings are presented using the same structure as mentioned in Chapter Five.

Chapter Seven: LSS road map to reduce medication errors

The chapter commences by reviewing the frameworks/roadmaps of Lean, Six Sigma and LSS proposed for healthcare sectors. The selected frameworks/roadmaps are further evaluated based on the different key characteristics, showing the limitations of each framework/roadmap. Thereafter, the chapter provides the details of the key steps of the LSS roadmap developed by the researcher to successfully implement LSS for the reduction of medication errors.

Chapter Eighth: Discussion of key findings

This chapter aims to discuss the key findings from the action research in Hospital A and Hospital B and the proposed LSS roadmap with respect to the four research questions identified in Chapter One. These key findings are further compared with the literature.

Chapter Nine: Conclusions, contribution to research and suggestions for future research

The chapter explains how the research questions identified in Chapter One were answered. Practical contribution is further indicated. Finally, the limitations and suggestions for future research directions are identified.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of Lean, Six Sigma, and Lean Six Sigma (LSS) intervention to reduce medication errors in hospitals. The review first analyses existing knowledge regarding Lean, Six Sigma and LSS in the healthcare sector. Subsequently, the review explores the incidences and impacts of medication errors, showing the importance of this study. The systematic review of tools and techniques, benefits, challenges, and factors leading to the success of LSS application in hospitals in order to reduce medication errors are further examined. This review contributes to the identification of research gaps, thus justifying the research questions for the study.

2.2 Lean, Six Sigma and Lean Six Sigma

Lean originated from the Japanese automobile industry, principally known as the Toyota Production System and was then popularized by the book entitled 'The machine that changed the world' by Womack *et al.* (1990). The customer-centric Lean philosophy focuses on the elimination of waste from the process, thus increasing speed and reducing operational costs. In healthcare, waste could refer to any activities that patients do not want to pay for and which do not add value to the healthcare service in the patient's view.

The concept of Lean focuses on understanding value from the customers' perspective, with activities that do not serve customers' needs considered for elimination from the process (Womack and Jones, 2003; Antony *et al*., 2019b). The principles of Lean are based on the assumptions that organizations comprise activities that contribute to the process known as the value-stream which is linked to the concept of value, waste reduction and continuous improvement (Womack and Jones, 2003).

The concept of Six Sigma was introduced by Bill Smith, an engineer at Motorola in the mid-1980 (Antony, 2006). Six Sigma was popularized by the general electric (GE) and their former CEO Jack Welch (Furterer, 2014). GE capital introduced Six Sigma to the financial service industry and the R&D operation in the form of design for Six Sigma (DFSS) (Snee, 2010). The success of Six Sigma in Motorola not only achieved Six Sigma quality level, but also focused on the reduction of the defect rate in processes through the use of statistical tools and techniques (Antony *et al*., 2006). The ultimate goal of Six Sigma is to improve the level of process performance and capability.

Six Sigma is a business management strategy and a data-driven methodology, which aims to reduce variation within a process that can result in defects or errors. It is a problem-solving methodology which aims to identify and eliminate the causes of defects or mistakes in a business process by focusing on customer requirements. Sigma stands for the rate of measurable variation in a given process, with an associated target of less than 3.4 failure or defect errors per million opportunities (Revere *et al*., 2004; Chakrabarty and Tan, 2007).

Lean and Six Sigma, integrated in the 1980s as Lean Six Sigma (George, 2003). The combination of Lean and Six Sigma is important because Lean enables organizations to accelerate process speed, while Six Sigma enables organizations to consistently maintain statistical control of a process and manage variation (George, 2002). Lean and Six Sigma integration contributes to better outcomes together rather than separately (Salah *et al*., 2010).

LSS is essential as organizations and individuals require a methodology to drive process improvement through variation and waste reduction (Snee, 2010). LSS can improve complex processes and quality of care, patient safety, and staff and patient satisfaction. Key features that differentiate LSS from previous quality improvement approaches include: 1) the integration of human factors (e.g. leadership and customer focus) and process improvement aspects (e.g. process capability and process management); 2) improved bottom line results; and 3) a structured Define-Measure-Analyze-Improve-Control (DMAIC) approach (Snee, 2010; Antony, 2011). In process improvement strategies such as LSS, senior leaders are typically involved in the selection of strategic projects which are aligned with the voice of the customer. This is facilitated by using the Hoshin Kanri tool (Tennant and Roberts, 2001). The participation of senior management was never emphasized in the majority of previous quality improvement initiatives, including TQM.

2.3 Lean, Six Sigma and Lean Six Sigma in Healthcare

LSS has become one of the most powerful business improvement methodologies over the last decade (Antony *et al*., 2017a). It has been applied in multiple industry sectors: manufacturing and engineering (42 per cent), service (32 per cent), healthcare (18 per cent) and other sectors (8 per cent) (Radnor, 2010). The following sections explain Lean, Six Sigma and LSS application in healthcare, followed by Lean and Six Sigma methodology and its tools and techniques. This review provides the current knowledge of

Lean, Six Sigma and LSS in healthcare for the researcher which can assist the research to bring theory (e.g. LSS) into both hospitals.

2.3.1 Lean in healthcare

The seven aspects of waste found in the process of manufacturing have been applied within healthcare organizations as shown in Table 2.1 (NHS Institute for Innovation and Improvement, 2007). Toussaint and Gerard (2010), however, included an eight waste which is talent, for example, failure to train emergency technicians and doctors in a new diagnosis technique.

Table 2.1 The seven aspects of waste in manufacturing as applied to healthcare

Manufacturing waste	Description	Example in healthcare
Transportation	Moving materials unnecessarily	Staff walking to the other end of a ward to pick up notes
Inventory	Excess work in progress or stock	Overstocking in storerooms Patients waiting for discharge
Motion	Unnecessary people's actions e.g. walking and searching	Unnecessary staff movement for paperwork
Waiting (delay)	People are unable to process their work because they are waiting for people, equipment and information	Waiting for patients, results, prescriptions, and medicines and for doctors to discharge patients
Overproduction	Producing more than is needed, or earlier than needed by the next process	Requesting unnecessary tasks from pathology Unnecessary treatment
Over-processing	Producing unnecessary process steps that do not add value	Duplication of information Unnecessary forms
Defects	Rework due to faulty processes	Readmission because of failed discharge Adverse drug reaction

Source: adapted from NHS Institute for Innovation and Improvement (2007)

Lean was first applied in the manufacturing industry and has been widely adopted in healthcare delivery (Antony *et al*., 2019b). As the recent literature by Radnor (2010) showed, 51 per cent of process improvement methodologies used in service sectors focus on Lean and 35 per cent on health services. Another literature review by Brandao De Souza (2009) revealed that just over half (57 per cent) of the employment of Lean in healthcare occurs in the USA, followed by the UK which accounted for 29 per cent, about 5 per cent in Australia and another 9 per cent internationally. Lean's relative adaptability

can be attributed to high levels of staff empowerment to contribute to, and benefit from, continuous improvement (Ballé and Régnier, 2007; Brandao de Souza, 2009; Curatolo *et al*., 2014). Applying Lean in the healthcare sector, particularly in hospitals, has resulted in notable improvements in quality of care, patient safety, staff and patient satisfaction (Brandao de Souza, 2009; Cheng *et al*., 2015; Costa and Godinho Filho, 2016). The implementation of Lean is favoured by healthcare managers worldwide because it potentially combines cost reduction with an outstanding standard of health service to the patient, it is easy to understand and is straightforward to use by healthcare staff (Curatolo *et al*., 2014).

Jadhav *et al.* (2014) asserted that the implementation of Lean has met with many challenges and barriers. However, there is an increasing use of Lean application in healthcare sectors (Jorma *et al*., 2016; Brandao De Souza, 2009). The existing literature has shown that Lean has been applied in hospital settings, clinical specialties and healthcare fields (Mazzocato *et al*., 2010).

Previous research findings show that the employment of Lean has contributed to immense benefits in several areas of healthcare sectors. The most common areas where improvements have been achieved by the application of Lean include time-saving, effective cost production, error or mistakes reductions, and improved staff and patient satisfaction (Mazzocato *et al*., 2010). However, there is a limitation in the use of Lean. As identified by Antony *et al.* (2017a), Lean is not appropriate to solve complex problems that require a large amount of data collection and analysis and advanced statistical tools. On the other hand, Six Sigma is a business strategy and philosophy that could be used to eliminate the root causes of complex problems occurring within the process steps. The next section will discuss the application of Six Sigma in healthcare.

2.3.2 Six Sigma in healthcare

Six Sigma was first applied in the manufacturing industry and has widely commanded attention subsequently in healthcare delivery. The Commonwealth Health Cooperation was one of the first healthcare organizations implementing Six Sigma in 1998 in the USA (Thomerson, 2001). This was facilitated by a General Electric consultant which contributed to positive outcomes with a 33 per cent increase in radiology and 21.5 per cent cost reduction (Laureani *et al*., 2013). Red Cross Hospital in Beverwijk in the Netherlands was one of the first healthcare organizations outside the USA implementing Six Sigma with the support of the Institute for Business and Industrial Statistics at the

University of Amsterdam, and after a three-year implementation, $1.2M was saved (Laureani *et al*., 2013).

Six Sigma methodology is a powerful improvement methodology which has assisted improvements in healthcare delivery (Taner *et al*., 2007). The consequence of moving to the higher sigma level has resulted in patient and physician satisfaction, reduced overtime, reduced patient waiting times, increased revenues, and an enhanced quality of life (Taner *et al*., 2007). In the healthcare industry, Six Sigma projects have mainly focused on direct care delivery, administrative support and financial administration (Antony, 2006). Nevertheless, Landek (2006) claims that Six Sigma would not be able to apply in hospitals. Aboelmaged (2011) further argued that the successful implementation of Six Sigma is difficult to achieve. Similarly, Antony *et al.* (2019a) identify several limitations of Six Sigma. For example, the initial cost of LSS implementation in an organization is high. However, many leading healthcare organizations have successfully implemented Six Sigma and has resulted in important outcomes such as reduced emergency room cycle time, increased timely completion of medical records, increased bed availability and a reduction in medication errors (Gijo *et al*., 2013). An application of Six Sigma has been applied in different healthcare services such as the laboratory (Elbireer *et al*., 2013), emergency care (Scalise, 2003) and ambulatory care (Jackson and Woeste, 2008).

The comparison between Lean and Six Sigma is presented in Table 2.2. As indicated previously, Lean focuses on the elimination of waste from the process which results in improvement of speed and flow. Six Sigma, on the other hand, aims to reduce variation within a process which can result in defects or error reduction. However, the integration of Lean and Six Sigma, which is called Lean Six Sigma (LSS), can contribute to better outcomes than the separate implementation of each methodology (Bhat *et al*., 2014; Salah *et al*., 2010). The next section focuses on the concept of Lean Six Sigma.

Table 2.2 Comparison between Lean and Six Sigma

Attribute	Lean	Six Sigma
Aims	Elimination of waste	Variation reduction
Focus	Flow	Problems with unknown solution
Methodology	Identify value Identify value stream Create flow Establish pull Seek perfection	Define Measure Analyse Improve Control

Tools and Techniques	Typically, non-statistical tools	Statistical tools typically used (not applicable in all cases)
Appropriate	The first round of improvements	Complex problems

2.3.3 Lean Six Sigma in healthcare

LSS is a widely adopted and well-documented process improvement manufacturing methodology in use across all highly reliable and safe industries (Dumitrescu and Dumitrache, 2011). The major benefits of successful LSS implementation within the manufacturing domain include; increased profits and financial savings, increased customer satisfaction, reduced operational cost and cycle time and improved key performance metrics (Snee, 2010). Laureani *et al*. (2013) contend that LSS can contribute as much to healthcare as it has to manufacturing. While the Commonwealth Health Corporation successfully implemented Six Sigma in 1998, LSS has since been applied in other healthcare organizations, including, hospitals and healthcare functional areas (Thomerson, 2001).

As in other industries, LSS implementation in healthcare has encountered many barriers (Laureani *et al*., 2013), including large initial training investment (Taner *et al*., 2007) and obtaining baseline process performance data (Sehwail and DeYong, 2003; Antony *et al*., 2007; Taner *et al*., 2007). Despite such barriers, successful LSS implementation in hospitals has delivered patient waiting time reduction in a registration process (Bhat *et al*., 2014), reduced turnaround time in a medical records department (Bhat *et al*., 2016), and reduced of medication errors (Esimai, 2005; Benitez *et al*., 2007). Based on a review of four case studies using LSS to reduce medication errors, the researcher concluded that the greatest benefits were enhanced patient safety, increased patient satisfaction, reduced costs, and greater team communication and improved team dynamics (Trakulsunti and Antony, 2018). The application of LSS has been applied different healthcare functional areas such as emergency care (Parks *et al*., 2008), inpatient care (Yamamoto *et al*., 2010), and administration (Roberts *et al*., 2017).

In summary, Lean, Six Sigma and LSS have been employed in several types of healthcare service: general (non-specific areas), entire hospitals, clinical specialties (e.g. inpatient, outpatient, intensive care, emergency, surgery), diagnostic services (e.g. radiology, laboratory), and other (e.g. organ transplant centre, pharmacy, and nursing). A key process metric that has been used by healthcare delivery areas has been process time

improvements (38 per cent), defect rate (30.4 per cent), productivity (19.9 per cent) and medication errors (7.6 per cent) (Liberatore, 2013).

2.3.4 Lean and Six Sigma methodology

Lean methodology includes five key principles: define value; define value stream; create flow; establish pull based on customer requirement; and seek perfection (Womack and Jones, 2003). Its primary aim is to satisfy customer needs by eliminating waste and any activities that do not ultimately add value (as defined by the customer). Table 2.3 presents the five principles of Lean and its application in healthcare. The following explains the five key principles of Lean methodology.

1) Specify values from the customers

Identifying values from the customers' perspective is a critical first step for Lean thinking in healthcare. The customers are patients, though other customers include health care professionals, for example, pharmacists, physicians and nurses. Values can be any activities that improve patients' health, wellbeing and experiences (NHS Institute for Innovation and Improvement, 2007). For example, patients receiving the correct medication and high-quality care.

2) Identify the values stream

The aim of the value stream is to identify all process steps that create the healthcare service/product from start to end. Creating value stream identifies three types of activities in the process: create value, create no value but unavoidable and create no value and to be eliminated immediately (Womack and Jones, 2003). In practice, mapping the process should be conducted by healthcare staff who are involved in various process steps (Burgess and Radnor, 2013). Once the process is mapped by using process mapping tools (e.g. value stream mapping), duplicated steps, unnecessary work and wastage are exposed and can be removed from the process.

3) Make the process flow

This principle aims to make the process flow continuously without obstacles. Any activities that do not add value to the healthcare project/service or customer's perspectives should be eliminated from the process. Flow without any obstacles can reduce the processing time, lead time and operational cost (Womack *et al*., 1990)

4) Let the customer pull

Let the customer pull means align the supply of healthcare service/product with customer demand (Womack and Jones, 2003). All people, work, skills, material, and information should be pulled by the customer when needed. For example, in healthcare, the product such as medicines and medication equipment, are supplied to the patient when needed.

5) Pursue perfection

To strive towards perfection is the final principle of Lean methodology. This principle makes Lean become a part of the healthcare organizational culture. Continuous improvement of the process by further eliminating waste is important to achieve in an ideal process.

Table 2.3 The five principles of Lean and its application in healthcare

Lean Principles	Applications in Healthcare
1. Define value from customers' perspective	Activities that are valued by the patient such as less waiting time and delay, high standards and good service, receiving correct medication and not catching infections while in hospital.
2. Identify the value stream	Mapping all process steps from start to end that are involved in creating healthcare service/ product. For example, the medication process is mapped from the point where doctors prescribe medications to patients receiving the medications.
3. Make the process flow	Eliminating non-value added activities, for example: - Waiting for a bed, a doctor or medication - Patient waiting to be discharged - Unnecessary movement of staff, patients and equipment - Duplication information

4. Let the customer pull based on their requirements	Pull the patient to the next process step, based on demand, for example: - A ward phone for the next patient rather than waiting for the next request. - Staff release beds to patients in theatres. - A ward pulls patients from the Emergency Department when a bed is available.
5. Pursue perfection	All healthcare staff should strive towards perfection through continuous improvement by further elimination of waste from the process.

Source: adapted from NHS Institute for Innovation and Improvement (2007)

Six Sigma has the ability to reduce variability within processes by the use of two major methodologies: DMAIC and Design for Six Sigma (DFSS) (Aboelmaged, 2011). DMAIC is a problem-solving methodology which consists of five phases of the continuous improvement cycle:

- **The define phase** – this phase aims to identify the scope and goals of the projects (Gijo *et al*., 2013; Bhat *et al*., 2014) and problems associated with the process that needs to be improved.
- **The measure phase** – this phase aims to collect data from the process in order to understand the baseline performance of the process in term of process capability and sigma rating, and validate the measurement system (Pande *et al*., 2000; Gijo and Antony, 2014; Malek and Desai, 2015).
- **The analyse phase** – the primary aim of this phase is to identify the root causes of the problems, which have to be eliminated in order to reduce the variation from the process (Chiarini, 2012; Elbireer *et al*., 2013).
- **The improve phase** – this phase aims to identify and implement solutions for each of the selected root causes in order to improve the process performance (Bhat *et al*., 2014; Sanders and Karr, 2015).
- **The control phase** – this phase aims to ensure that the improvement made in the improve phase can be sustained in the long term (Gijo and Antony, 2014; Al Kuwaiti and Subbarayalu, 2017).

Six Sigma methodology is used to tackle problems in existing processes and the stringent assumption that is always made is that the design is robust (Trakulsunti *et al*., 2018). In

contrast, DFSS methodology employs the following five phases: define; measure; analyse; design; optimise and verify (DMADOV) to replace existing systems with new processes (Albiliwi *et al*., 2017). As Snee (2010) and Salah *et al.* (2010) highlighted DMAIC improvement framework has been proved successful in improving processes and has been widely adopted by many practitioners attempting to improve processes. The five steps of DMAIC are easy to follow to determine the root causes of problems within processes (Snee, 2010; Antony *et al*., 2016). In this research, DMAIC methodology was applied to understand and eliminate the root causes of the problems existing in the dispensing process. The five phases of DMAIC methodology were used as a core structure framework, integrated with Lean tools, to improve the dispensing process. The next section examines common Lean and Six Sigma tools and techniques used in the healthcare sector.

2.3.5 Tools and techniques of Lean Six Sigma in healthcare

Several tools and techniques from the toolboxes of Lean and Six Sigma have been applied in the sequence of DMAIC methodology. Six Sigma tools are analytical, statistical and advanced statistical, while Lean tools are mainly non-statistical tools (Salah *et al*., 2010). In reviewing the current literature, the details of the common tools and techniques applied in each phase of DMAIC in healthcare have been summarised in Table 2.4.

In the define phase, project charter, SIPOC, critical-to-quality (CTQ) characteristics and process mapping are commonly used to define the scope of the project and identify problems associated with processes. In the measure phase, data collection plan and process capability analysis are used to ascertain the baseline performance, showing the current state of the problem. Subsequently, the root causes of the problems are identified in the analyse phase. The common tools used in this phase include value stream mapping, brainstorming, cause and effect analysis, Gemba and hypothesis testing. The next phase is the improve phase which aims to identify and implement solutions for each of the selected root causes. The common tool used in this phase is Poka-yoke. Finally, in order to control the sustainability of process performance, control chart and run chart are used in this phase.

In could be observed that in service organizations, such as hospitals, banks, and financial services, the problems could be tackled by using the simple tools of Lean and Six Sigma. However, it is important to choose the correct tools and techniques from Lean and Six

Sigma toolboxes to solve the different problems which lead to the success of LSS implementation.

Table 2.4 Common tools and techniques used in the various phases of Six Sigma methodology

Six Sigma methodology phases	Common tools and techniques
Define	**Project Charter** covers all necessary details of the project including the title, objectives, team members, schedules, and expected benefits (Gijo *et al*., 2013). It helps the team to focus on the project goals and clarifies the roles and responsibilities of each team member (Bhat *et al*., 2014). **SIPOC** helps all team members to clarify the scope of the project and to understand the overall picture of the process (Gijo and Antony, 2014). **Process mapping** visually presents the current state of the process which helps to understand existing problems such as poor flow, rework loops and delays etc. (George *et al.*, 2005). It can be used to compare and contrast the actual flow and the ideal flow to identify the opportunities for improvement (Antony *et al.*, 2019b).
Measure	**Data collection plan** is prepared by the project team to identify the type of data to be collected, unit of measurement, type of sampling techniques and the measurement system to be used to collect data (Bhat *et al*., 2016) to ensure that the data will be useful and valid. **Process capability analysis** shows the defects per million opportunities (DMPO) and could

	further identify the level of sigma; this is considered as the baseline performance of the process (Bhat *et al*., 2016). **Critical to Quality (CTQ)** is a measurable characteristic of product/service which is linked to the customer's requirement gained from the voice of customer (VOC) data collection (Chakrabarty and Tan, 2007; Antony *et al.*, 2016).
Analyse	**Value stream mapping (VSM)** is used to capture all important flow of products, information and materials in a process and important metrics (George *et al.*, 2005). It enables the identification of non-valued added activities in the process and eliminates them. **Brainstorming** is a tool used by all of the team members to generate ideas for solutions to a specific problem. Effective brainstorming involves the recording of ideas generated during the session (Jones and Lambertus, 2014). **Cause and effect analysis** is used to identify the potential causes of the problems through the brainstorming session of all team members (Chiarini, 2012). **Gemba** is used to validate potential causes by observing the process (Bhat *et al*., 2014). The process is observed at a specific time and the occurrence and nonappearance of the specific cause are recorded (Bhat *et al*., 2014). **Hypothesis tests** are used to prove or disprove assumptions about a process, to validate the causes and to compare the process before and after improvement (Antony *et al*., 2016).

Improve	**Poka-yoke** or mistake-proofing is making it impossible for an error to occur by the use of any devices or methods (George *et al*., 2005) and stopping an error before passing to another phase of the work.
Control	**Run chart and Control chart:** A run chart is used to look for trends and patterns in the data in order to identify the special cause variation. A control chart is similar to run charts in that it displays the data in time order (George *et al*., 2005). However, control limits are added in the control chart to identify special cause variation when the process is not operating within an acceptable range of variation.

The following sections review the benefits, challenges and critical success factors. It is important to review these elements in order to gain a broad understanding of the benefits, challenges and success factor of LSS implementation and assist the researcher to successfully apply LSS in both hospitals and develop the LSS roadmap.

2.3.6 Benefits of Lean Six Sigma in healthcare

The implementation of LSS has provided potential benefits in several areas throughout healthcare organizations as aforementioned. The following explains the most areas which have been targeted by LSS application including Surgery/Operating rooms, Emergency Department (ED) and Outpatient Department (OPD).

- Surgery/Operating rooms

The Surgery Department is one of the commonest of LSS applications in healthcare because quality, appointment lead time, efficiency and costs are essential aspects for the provider (Ortiz Barrios and Felizzola Jiménez, 2016). Cima *et al.* (2011) implemented LSS to improve the operating room regarding efficiency and financial performance. The study resulted in improvement of on-time start which increased by 28-32%, leading to a reduction in the number of cases that needed to be seen after 5 pm and improved turnover time. They also mentioned that the key elements that enhance operating room efficiency are process mapping, top management support, and staff engagement. Furthermore,

Niemeijer *et al.* (2013) employed LSS to reduce the length of stay (LOS) of elderly patients with hip fractures. Their intervention achieved a reduction of average LOS by 4.2 days and the average duration of surgery by 57 minutes.

- Emergency Department

Emergency department is the frontline for patients arriving at the hospital in need of immediate care. It has been challenging to achieve a rapid care for patients coming into the ED and this, combined with a delay in discharging such patients, which has contributed to the inefficient flow of patients. A study by Sanders and Karr (2015) employed LSS to reduce turnaround time (TAT) for emergency department specimens. However, the results of the study showed not only the reduction of TAT, but also contributed to an improvement in other processes in the hospital. Furterer (2014) implemented LSS to reduce patient LOS and the number of patients who left without being seen in the hospital's emergency department. There was a 31% reduction in LOS and the percent of patients who left without being seen was reduced from 6.5 to 0.3%. Similarly, Johnson *et al.* (2004) worked on this area aiming to reduce patient LOS and process errors.

- Outpatient Department

Gijo and Antony (2014) addressed the long patient waiting time problem in the OPD by implementing LSS methodology. As a result of the study, the average waiting time decreased from 57 minutes to 24.5 minutes and also contributed to an improvement in patient satisfaction improvement, a reduction in delay with treatment and a faster recovery for patients. Lin *et al*. (2014) combined the concept of LSS and simulation methods to reduce patient waiting time in the Ophthalmic OPD. This study was able to reduce the average patient waiting time by 23.7%. Another case study was conducted by Bhat *et al.* (2014) who implemented LSS to diminish the cycle time of outpatient department service in a rural hospital and, as a result of this, the cycle time for the process decreased from 4.27 minutes to 1.5 minutes. LSS has been mostly implemented to reduce patient waiting time in the OPD.

In summary, it has been shown from this review that the reduction of TAT, LOS, patient waiting time and number of patients leaving without being seen have been the main focus of LSS projects. However, most of the studies do not mention the barriers and challenges

of employing LSS faced by healthcare practitioners. The next section aims to present barriers and challenges of LSS implementation in healthcare.

2.3.7 Barriers and challenges of implementing Lean Six Sigma in healthcare

There are several barriers and challenges which the healthcare industry has faced during the implementation of LSS. An impediment to the implementation of LSS in healthcare is the initial large investment required for Six Sigma training (Taner *et al*., 2007). Another major challenge is the difficulty of obtaining the baseline data on process performance (Sehwail and DeYong, 2003; Antony e*t al*., 2007; Taner *et al*., 2007). It is also difficult to identify the process which can be measured in term of defects or mistakes per million opportunities in the healthcare industry (Taner *et al*., 2007). Frings and Grant (2005) suggested that the length of time for a project and governmental regulation are potential barriers in LSS implementation.

Furthermore, healthcare provision is subject to uncontrollable factors such as sociological and personal considerations, and it is difficult to measure patient satisfaction in a hospital environment (Antony *et al*., 2007; Gijo *et al*., 2013). Taner *et al.* (2007) identified obstacles to the implementation of LSS in healthcare organizations including lack of financial resources, lack of human resources, lack of time, lack of leadership, lack of training, poor project selection and internal resistance. These challenges may not appear in every hospital. It might rely on the commitment and engagement of top leaders from different hospitals. The next section identifies several critical success factors which help healthcare organizations to achieve the success of LSS projects.

2.3.8 Critical success factors (CSFs) of Lean Six Sigma in healthcare

Critical factors are important to the successful implementation of any quality improvement initiates (Desai *et al*., 2012). The following CSFs are the ones most frequently reported in the literature, based on the current review. Many researchers mention that the support and commitment of top management is critical to the success of the project (Tsironis and Psychogios, 2016; Alhuraish *et al*., 2017). Antony *et al.* (2007) suggested that the implementation of LSS project should begin with a two-day overview of LSS methodology for the top management, ensuring buy-in and commitment for the LSS implementation. Linking LSS to business strategy and customer voice is an essential factor leading to the success of the LSS project (Desai *et al.*, 2012; Alhuraish *et al*., 2017). However, Laureani *et al.* (2013) further stated that the clinic staff commitment to process

improvement is also considered as an important success factor. Moreover, an appropriate training and education for the LSS project team and an understanding of LSS methodology and its tools and techniques can contribute to effective LSS employment (Antony *et al*., 2007; Alhuraish *et al*., 2017). The LSS project team can choose the right tools and techniques in each phase of LSS methodologies.

Another aspect is project prioritisation and selection (Desai *et al*., 2012; Bhat *et al*., 2016). Selection of the right project can help the management and staff to gain the benefits and strengths of LSS (Bhat *et al*., 2016). Specifying the infrastructure including senior management leadership, Champions, Master Black Belts (MBBs), Black Belts (BBs) and Green Belts (GBs) are also needed for success (Snee, 2010). Table 2.5 summarises the benefits, challenges and success factors of LSS implementation in healthcare.

Table 2.5 Benefits, challenges and critical success factors of LSS in healthcare

Benefits	Challenges	Critical Success factors
• Improved operating room efficiency and financial performance (Cima *et al*., 2011) • Reduces the delay of first patients arriving in the operation room (Warner *et al*., 2013) • Reduces the length of stay (Johnson *et al*., 2004; Furterer, 2014) • Reduces turnaround time for emergency department specimens (Sanders and Karr, 2015) • Reduces patient waiting time in the OPD (Bhat *et al*., 2014; Gijo and Antony, 2014; Lin *et al.*, 2014)	• Requires large investment for training (Taner *et al*., 2007) • Difficult to obtain the baseline data on process performance (Sehwail and DeYong, 2003; Antony *et al*., 2007) • Difficult to identify processes that can be measured in terms of defect per million opportunities (Sehwail and DeYong, 2003) • Difficult to measure patient satisfaction in a hospital environment (Antony *et al*., 2007; Gijo *et al.*, 2013) • Lack of training and education (Taner *et al*., 2007) • Resistance to change (Antony *et al*., 2007)	• Top management support and commitment (Alhuraish *et al*., 2017; Tsironis and Psychogios, 2016) • Linking LSS to business strategy and customer's voice (Desai *et al*., 2012) • Appropriate training and education for the LSS project team (Antony *et al.*, 2007) • Understanding of LSS methodology and its tools and techniques (Antony *et al*., 2007) • Project prioritisation and selection (Desai *et al*., 2012; Bhat *et al*., 2016)

2.4 Introduction to medication errors

The section below describes the medication use process, the definition of medication errors, types of medication errors and causes of medication errors. Then it considers the definition and types of dispensing errors. Finally, the incidence and impact of medication errors are explained.

2.4.1 Medication use process

The medication use process shows the steps involved from the beginning until patients get the medication and leave hospital. In hospital, the process of medication use normally consists of five stages: prescribing, transcribing, dispensing, administration and/or monitoring, as shown in Figure 2.1 (Aldhwaihi *et al*., 2016).

Figure 2.1 Medication use process
Source: adapted from Weant *et al.* (2014)

In the prescribing stage, physicians play an important role in prescribing the right medication to the patients. Prescriptions of medication can be ordered by a handwritten prescription, computerised physician order entry (CPOE), electrical or verbal order from physicians to pharmacists in order to give instructions on how to dispense medication to patients (Velo and Minuz, 2009). Then the details of the prescribed medication are manually copied by nurses onto the medication administration (MAR) chart or entered into the medication administration record (Elliott *et al*., 2016). Medications are delivered or dispensed by pharmacists in the dispensing stage (Yoelao *et al*., 2014). Administration of medications by nurses is the final step of the medication process (Berdot *et al*., 2016). However, physicians, certified medication technicians, patients, and family members can also administer medications (Hughes, 2008).

Finally, the monitoring stage involves the activities, which aim to monitor the impact of medication on the patients (Management Science for Health, 2012). This stage refers not

only to monitoring inpatients but also includes patients who are discharged home, when the aim is to ensure that appropriate follow-up happens (Weant *et al*., 2014). The activities of each phase of the medication use process are summarised in Table 2.6

Table 2.6 Details of each phase in the medication use process

Medication process steps	Activities
Prescribing	Evaluate patient Establish a need for medicine Select the right medicine Determine interactions and allergies Prescribe medicine
Transcribing	Transcribe prescription/order Transit to pharmacy
Dispensing	Review prescription order Confirm transcription Contact prescriber for discrepancies Prepare medicine Distribute medicine
Administering	Review prescription order Confirm transcription Review warnings, interactions, and allergies Evaluation of patient Administer medicine
Monitoring	Assess patient's response to a medicine Report and document results

Source: adapted from US Pharmacopeia (2004)

2.4.2 Definition of medication errors

According to the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP), a medication error is a "preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing, order communication, product labelling, packaging, and nomenclature, compounding, dispensing, distribution, administration, education, monitoring, and use" (NCC MERP, 2017, para. 1). Furthermore, medication errors have been defined by several researchers as any errors that occur at every stage of the medication process, stemming from prescribing, transcribing, dispensing, administration by the nurse, and/or monitoring (Franklin *et al*., 2005; Lisby *et al*., 2005; Baril *et al*., 2014). Franklin *et al.*

(2005) further pointed out that a medication error may or may not cause harm to the patient, but it is considered to be preventable.

2.4.3 Types of medication errors

Types of medication errors can be classified based on different factors such as the medication use process and the underlying cause (Table 2.7). Moreover, medication errors can be classified by their errors index according to the severity of the outcomes as adopted by the National Coordinating Council for Medication Error Reporting and Prevention, as shown in Figure 2.2.

2.4.4 Causes of medication errors

A number of studies have identified the common causes of medication errors which are summarised in Table 2.8 (American Society of Health-System Pharmacist, 1993; Roy *et al*., 2005; Jhanjee *et al*., 2011; Cheragi *et al*., 2013). The causes of medication errors are primarily based on different factors such as manpower, environment, method, and machinery. Types of various medication errors and their causes are summarised in Table 2.9.

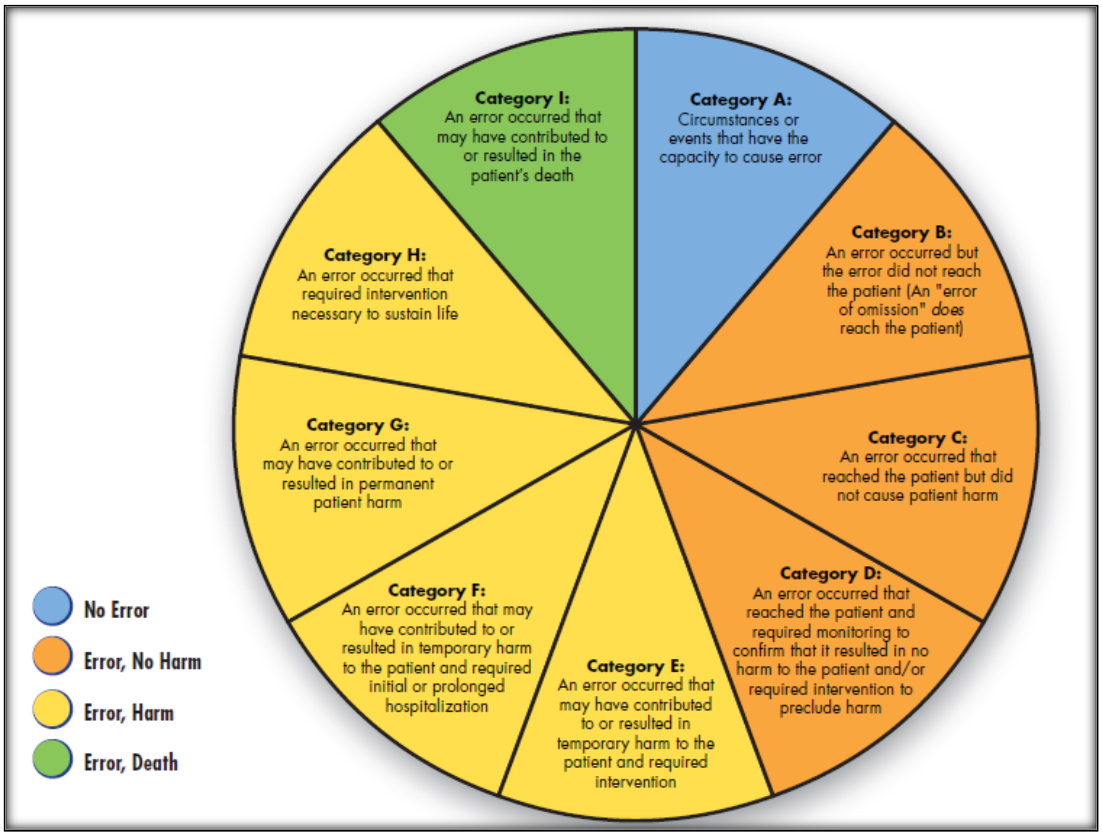

Figure 2.2 NCC MERP index for categorizing medication errors

Source: NCC MERP (2017)

Table 2.7 Classification of medication errors

Research Title	Classification of Medication Errors
Medication Errors (WHO, 2016)	Based on medication process • Prescribing errors • Transcribing errors • Dispensing errors • Administration or monitoring errors
Medication Errors in Clinical Practice (Jhanjee *et al*., 2011)	Based on the underlying causes • Omission errors • Wrong dose error • An unordered error • Wrong dosage form error • Wrong time error • Wrong route error • Deteriorated drug error • Wrong rate of administration error • Wrong administration technique errors • Wrong dose preparation error • Extra dose error

Table 2.8 Causes of medication errors

Research Title	Causes
Medication errors : causes & prevention (Roy *et al*., 2005)	Failed communication Poor drug distribution practice Workplace environmental problems that increase job stress Complex or poorly designed technology Access to a drug by non-pharmacy personnel Dose miscalculation Lack of information to prescribers Lack of patient information Lack of patients'understanding of their therapy
Medication Errors in Clinical Practice (Jhanjee *et al*., 2011)	Performance deficit Procedure or protocol not followed Miscommunication Inaccurate or omitted transcription Improper documentation Drug distribution system error Knowledge deficit Computer entry error Lack of system safeguard
ASHP guidelines on preventing medication errors in hospitals (American Society of Health-System Pharmacists, 1993)	Ambiguous strength designation on labels or in packaging Drug product nomenclature Equipment failure Unreadable handwriting

In a hospital environment, the medication use process consists of key stages as identified in Figure 2.1, depending on the hospital system. Medication errors most commonly occur in the prescribing, dispensing and administration stages (Aldhwaihi *et al*., 2016). The growing body of research on this subject largely focuses on reducing the number of prescription and administration errors (Kaosayapandhu, 2013). Although rates of dispensing errors are generally low, the potentially fatal consequences with any error necessitates further research, interventions and improvements in the pharmacy distribution system in order to reduce these errors (Crane and Crane, 2006; Cheung *et al*., 2009). The majority of research to date has focused on the investigation of medication error in the healthcare sector, with several studies relating to dispensing error. However, these latter studies focus primarily on identifying the type of dispensing errors that occur without reference to the strategies which are employed to mitigate against such errors (Aldhwaihi *et al*., 2016). Therefore, this research focuses on reducing the number of dispensing errors in the inpatient pharmacy setting. The next section explains the definition and types of dispensing errors.

Table 2.9 Types of medication errors and their causes

Stages of Medication Errors	**Types**	**Causes**
Prescription errors (Franklin *et al.*, 2011; Slight *et al.*, 2013)	Omission of medication Inappropriate dose Incomplete prescriptions Duplication Illegible handwriting Inappropriate abbreviation Inappropriate frequency or dosing schedule Inappropriate dose Incorrect route Allergic to prescribed medication	Work enviroment - Heavy workload - Time pressure - Distractions/Interruptions Individual - Inexperienced staff - Tiredness/stress Task factors - Lack of standardisation in prescribing - Guidelines, policies unavilable Computer system - Wrong medication selection - Excessive alerts Patient - Complex clinical disease - Poor communication with patients
Transcription errors (Knudsen *et al.*, 2007)	Wrong dose Omission Wrong schedule of administration Wrong start/stop time Wrong medication Miscalculation	Pharmacists incorrectly read/decode prescriptions. Pharmacists incorrect selection of medication in the computer system Incorrect manual data entry

		Lack of concentration caused by interruptions Unclear handwritten prescriptions
Dispensing errors (James *et al.*, 2009; Kaosayapandhu, 2013; Rajah *et al.*, 2018)	Dispensing wrong medication Dispensing wrong strength Dispensing wrong dosage form Dispensing wrong quantity Dispensing expired/deteriorated medication Issued to wrong patients Failure to dispense medications (Omission Errors) Dispensing with the wrong information on the label (e.g. wrong medication name, strength, dosage form)	Workload Look-alike sound-alike medications Interruptions Poor handwriting Subject to time constraints Staff shortage Fatigue of healthcare providers
Administration errors (WHO, 2003; Keers *et al.*, 2013)	Patient record errors Patient identification errors Medication is given to the wrong patient. Wrong route of administration Medication is given to a patient with a known allergy. Administration of a medication that was not prescribed. Wrong medication or intravenous therapy (IV) fluid administered	Misidentification of medication or patient Misreading a medication label/product or prescription Problems with policies or procedures Problems with equipment used to aid medication administration (e.g. insufficient and malfunctioning equipment) Communication Distractions and interruptions
Monitoring errors (Aronson, 2009; Weber, 2017)	Inadequate monitoring Poor clinical monitoring Report incorrect patient's results	Lack of necessary monitoring Failure to use appropriate clinical or laboratory data for assessment of patient response to the prescribed therapy Failure to alter therapy when required

2.4.5 Dispensing errors

A. Definition

Dispensing errors have been commonly defined by several researchers as a discrepancy between a prescribed medication by physicians and the medications that the pharmacist dispenses to the patient or delivers to different wards (Aldhwaihi *et al*., 2016; Cheung *et al*., 2009; Rajah *et al*., 2018). However, James *et al.* (2009) argued that this definition does not distinguish between errors that can be detected within or outside the pharmacy department. Aldhwaiihi *et al.* (2016) further identified that dispensing errors refer to any

errors happening in every stage of the dispensing process whether uncovered in the pharmacy department or after the medications have already been distributed to the patient or delivered to different wards. The errors that are detected after the medications have left the pharmacy department can be defined as undetected dispensing errors. In contrast, errors that are detected and reported within the pharmacy department before medication is delivered to the patient or different wards can be defined as near-miss(es) and detected dispensing errors (Aldhwaihi *et al*., 2016; James *et al*., 2009). Even though these errors are considered to be less harmful, it could lead to dispensing errors due to inefficient counter checking by pharmacists (Rajah *et al*., 2018).

The dispensing of medicines involves preparing and giving medicine to a patient, based on a prescripton or medication order (Weant *et al*., 2014). Dispensing is complex and errors can occur at any stage, from receiving medication orders/prescriptions to supplying medication to a specific patient (James *et al*., 2009). If not detected in the pharmacy department, errors may result in injury, death and/or economic loss. Interestingly, the dispensing process within a hospital setting (e.g. inpatient service) is deemed to be more complex than that of non-hospital settings (e.g. community pharmacy). When compared with a community pharmacy, hospital pharmacists dispense through a more complex regimen which can lead to a high occurrence of errors (Aldhwaihi *et al*., 2016). In this study, incorrect medication selection and incorrect entry of medication orders are considered detected dispensing errors (i.e. near misses). The errors undetected by pharmacists are considered as undetected dispensing errors.

B. Types of dispensing errors

Different categories are used to classify types of errors that occur during the dispensing process. A recent systematic review conducted by Aldhwaihi *et al.* (2016) concluded that one of the most common types of dispensing errors is dispensing the wrong medication. Other frequent types of undetected and detected dispensing errors are dispensing the wrong strength, wrong dosage form, wrong quantity, and selection of wrong medication. Nevertheless, the most common type of dispensing error in the inpatient service is dose omission of prescribed medications (Aldhwaihi *et al*., 2016). Table 2.10 presents the common types of dispensing errors and their definition.

Table 2.10 Common types of dispensing errors, definitions and examples

Types of dispensing errors	Definitions	Examples
Wrong medication	Medication is prescribed but another one is dispensed.	Potassium chloride injection prescribed but Calcium Gluconate injection dispensed.
Wrong strength	A strength lower or higher than that prescribed is dispensed.	Febrex 500 mg Tab prescribed but Febrex 650 mg dispensed.
Wrong dosage form	A form of a medication is dispensed which is different from that prescribed for the patient.	Emeset 4 mg tab is prescribed but dispensed as Emeset 4 mg injection.
Wrong dose	The dose of medication dispensed is greater or lower than prescribed by physicians.	Prescription is for 25 mg of Captopril and a 50 mg dose is dispensed.
Wrong quantity	The quantity of drug dispensed is higher or lower than that prescribed.	Karvol Plus Inhalant capsule x 3 are prescribed but only 2 are dispensed.
Wrong patient	The medication is dispensed to the wrong patient.	Phenytoin was prescribed to patient A but is dispensed to patient B.

Source: adapted from Sekhar *et al.* (2011), Teixeira and de Cassiani (2010), and Caspi *et al.* (2005)

2.4.6 Incidence and impacts of medication errors

A report published by the Institute of Medicine (IOM), *To Err Is Human: Building a Safer Health System*, has raised attention regarding the problem of preventable adverse drug events resulting from medication errors in the healthcare industry (Kohn *et al*., 2000). This report estimated that medication errors caused one out of every 131 outpatient death, one out of 854 inpatient deaths and 7000 deaths annually. This report has been widely cited in many published studies as a key message in raising patient safety awareness. Some studies have conducted a survey to study the perspective of healthcare professional on patient safety after the IOM report (Patel and Balkrishnan, 2010). The findings of all studies have suggested some approaches that could improve patient safety such as increasing the number of staff, implementing an error detection system and the use of information technology.

However, after 15 years of IOM report, the Institute for Healthcare Improvement (IHI) stated that patient safety has continually been compromised due to the healthcare system, despite some improvements according to two reports from the UK and the USA namely

'*Continuous Improvement of Patient Safety: The Case for Change in the NHS' and ' Free from Harm: Accelerating Patient Safety Improvement Fifteen Years'* (IHI, 2015). These reports point out that there is a long way to go to ensure an adequate level of safety for all patients. Several studies over the past decade have identified medication errors as a global issue with prescription errors in the UK, reportedly affecting 12% of all primary care patients and 38% of those aged 75 years and above (WHO, 2016). In the USA, medication errors cause at least one death every day and injure approximately 1.3 million people every year (U.S. Food and Drug Administration, 2016). In England, the researchers estimated that 237 million medication errors occur in the medication use process every year (Elliott *et al*., 2018). In Australia, the error rates of administration ranged from 15% to 20% (Runciman *et al*., 2003), while 58% of prescriptions in Mexico contained errors, predominantly due to dosage regimen and inappropriate drug selection (Zavaleta-bustos *et al*., 2008). In Canada, 4% of inpatients have experience with dispensing or administration errors (Covenant Health, 2015). In Vietnam, 28.8% of medication errors related to insulin mostly due to incorrect time of administration and preparation of insulin (Nguyen *et al*., 2015). In Thailand, however, the rate of medication errors in Thai hospitals has not been estimated due to a lack of national data (Chumchit *et al*., 2015) and a system for reporting medication errors. Evidence shows that medication errors contribute to patient injury and death and further contribute to a detrimental economic outcome.

- Economic impact

An accurate estimation of the economic burden on medication errors is necessary to inform the successful implementation of an intervention which focuses on reducing medication errors (Walsh *et al.*, 2017). Globally, the cost associated with medication errors is US$ 42 billion each year, which represents almost 1 per cent of the global expenditure on health (WHO, 2017a).

Several studies have estimated the cost of medication errors in healthcare settings. Walsh *et al.* (2017) systematically reviewed the economic burden associated with errors in the medication process in nine different countries over an 11-year period. The average cost per medication error per study from the review ranged from €2.58 to €111,727.08 (cost value were expressed in Euro 2015). The study identified that hospitalization costs are the most frequent parameters used to establish the economic impact of medication error. All the included studies have found that medication errors are a significant economic

burden in the healthcare sector due to an increase in financial costs or length of hospital stay.

In the emergency department, a medication error resulted in an increase of $268 in the total emergency department costs (Bowman, 2010). In the USA, inpatient injectable medications leading to preventable adverse drug events (ADEs) added $2.7 billion to $5.1 billion annually for the US payer, and added $600,000 extra cost per hospital (Lahue *et al*., 2012). In the UK, medication errors cost the National Health Service (NHS) up-to £770 million for adverse drug reactions and inpatient harm in the hospitals (Torjesen, 2014). The cost of medication errors ranged from £60 per error for inhaler medication to over £6 million associated with anaesthetic errors (Elliot *et al*., 2018). In the USA healthcare system, inpatient preventable medication errors approximately cost $16.4 billion annually (NEHI, 2008). In Australia, medication errors cost over $680 million each year (Australian Commission on Safety and Quality in Health, 2013). In Thailand, the National Health Security Office paid an average US$ 7,200 per case to 885 patients and/or their families who suffered from undesirable consequences of medication practices (National Health Security Office, 2016). In developing countries, the data associated with the incidence and economic impact of medication errors are lacking (Jhanjee *et al*., 2011). Walsh *et al.* (2017) pointed out that published studies had assessed the economic impact of medication errors predominantly in hospitals, and therefore there was a limitation regarding the economic impact from a primary care and patient perspective. Samp *et al.* (2014) further mentioned that the publication of medication error costs has several limitations owing to the difficulty of identifying all different types of medication errors, as most studies have focused on a specific healthcare setting.

Medication errors cost nations and different healthcare settings a large amount of money. Various countries – notably Canada, the USA, Sweden, and Japan – have put a considerable into minimizing medication errors by establishing medication error reporting systems (MERs) which can provide valuable information for healthcare professionals to prevent medication errors (Patel and Balkrishnan, 2010). It appears to be the situation that MERs only exist in developed countries. Salmasi *et al.* (2015) identified that the number of medication errors is consistently under reported around the world.

- Incidence of dispensing errors

Dispensing is a complex process (Aldhwaihi *et al*., 2016); where errors can occur at any stage, from receiving medication orders/prescriptions to supplying medication to a

specific patient. Dispensing errors are reported worldwide. In England and Wales, it has been estimated that 134,341 dispensing errors occur in community pharmacies each year, although pharmacists identify and correct the majority of these errors before medications are dispensed (James *et al*., 2009). In the USA, it has been estimated that four dispensing errors occurred every day per 250 prescriptions in 50 pharmacies (Flynn *et al*., 2003). A systematic review of dispensing error rates identified rates between 11.5% and 33.5% in Brazil, compared to rates between 0.016% to 3.6% in the UK, USA and France (Aldhwaihi *et al*., 2016).

James *et al.* (2011) stated that a small number of studies have been conducted to compare the rate of undetected and detected dispensing incidents. James *et al.* (2011) conducted a study to compare such incidents and concluded that there were significant differences between undetected and detected dispensing incidents in terms of rate and error types. This demonstrates that the dispensing errors rates in each hospital pharmacy vary depending on several factors, for example, types of dispensing errors (detected and undetected), research methods, number of beds, medications distribution system, and organizational culture (James *et al*., 2009; Kaosayapandhu, 2013; Aldhwaihi *et al*., 2016).

2.4.7 Technological interventions to reduce medication errors

A variety of technological interventions are being used to reduce medication errors including computerised physician order entry (CPOE), automated dispensing cabinets and bar-coding (NR and BMY, 2013). CPOE has been implemented to reduce prescription errors (Koppel *et al*., 2005). The CPOE allows physicians to electronically enter medication orders, laboratory, admission, radiology and transfusion orders (Kaushal *et al*., 2006). When CPOE is combined with clinical decision support (CDS) it can reduce prescribing errors, improve medication safety and hospital workflow (Kaushal *et al*., 2006; Brown *et al*., 2017). However, several studies have indicated that the CPOE system, with or without CDS, could contribute to the occurrence of medication errors in both primary and secondary care (Campbell *et al*., 2006; Koppel *et al*., 2005; Brown *et al*., 2017). Similarly, Koppel *et al.* (2005) claimed that most of the CPOE studies normally focus on its advantages, but CPOE may also contribute to new types of errors such as medication selection errors and specific issues (e.g. excessive alerts, conflicting or duplicated medication). For example, a study by Kopple *et al.* (2005) found that the use of the CPOE system resulted in 22 types of medication error risks. Importantly, CPOE is

normally not appropriate in developing countries because of resource constraints (Sanguansak *et al.*, 2012).

Automated dispensing machines or automated dispensing cabinets have been implemented to improve medication distribution and reduce dispensing errors and administration time errors (Chapuis *et al*., 2010; Weber, 2017). Automated dispensing machines are computer-controlled to secure medication storage and distribution which are located in a patient care unit (e.g. wards, ICU, ED) (Chapuis *et al*., 2010). The use of automated dispensing machines could decrease the time needed by the pharmacy department staff to dispense medication (Harolds and Harolds, 2016). However, if the automated dispensing machines are not used properly by clinical staff, it can result in several problems such as improper use of override access to medications and selection of the wrong medication.

Bar-coding has been widely implemented to reduce errors in the administration phase (Weant *et al*., 2014). A study conducted by Agrawal (2009) reported that the use of barcode technology can reduce transcription errors by 50.8% and administration errors by 27.3%. The nurse can scan the patient's identification bracelet against the unit dose of medication being administered (Agrawal, 2009). However, there are new sources of errors associated with the use of bar-code technology. These errors include mislabelling, inability to scan a barcode, lack of barcode, etc. (Cochran *et al*., 2007).

The above technological interventions can reduce errors in the medication use process, improve patient safety and save costs. However, the installation of these interventions and their maintenance is very costly (NR and BMY, 2013). Table 2.11 summarises limitations and problems regarding the use of technology interventions in hospitals. Moreover, others concerns that have not been mentioned in the table are: 1) these IT systems could produce more work for clinicians and cause workflow problems; 2) the current approach of technological intervention focuses on the functionality of the system, rather than solving the problem of usability by healthcare staff (Agrawal, 2009). The automated system should be considered as a tool to improve the medication use process rather than a permanent solution to solve problems in that process (American Society of Health-System Pharmacists, 2010).

Table 2.11 Benefits, limitations, and problems of technological intervention

Medication use process	Interventions	Benefits	Limitations and problems
Prescribing	Computerised Physician Order Entry (CPOE)	Reduces prescription errors Increases physician satisfaction Eliminates illegibly handwriting	Requires large capital investment and maintenance Loss of data and time when CPOE is shut down for maintenance
Dispensing	Automated dispensing machines	Minimizes the potential of dispensing errors and administration errors Enhances first dose availability and facilitates the timely administration of medications Reduces pharmacy's dispensing time	Requires large capital investment Lack of evidence to support that the use of the automated dispensing machine without the combination with CPOE can enhance patient safety
Administration	Bar-coding	Improves patient identification Increases accuracy when medications administered to patients Eliminates transcription errors	May create the risk of new errors

In addition, there are non-technological approaches that can be used to tackle medication errors such as medication reconciliation, education and training, use of 'tall man letter', improving the work environment and building a safety culture. Medication reconciliation is 'the process of comparing a patient's medication orders to all medications that the patient has been taking' (Weant *et al*., 2014, p.51). The reconciliation of these medications can avoid the occurrence of medication errors (e.g. omissions, duplication and drug interactions) when patients transition between hospitals or other care settings (Weant *et al*., 2014). However, there are some factors that contribute to transition which are related to adverse drug event errors including unreliable patient history taking, poor communication and flawed communication of drug regimens (Boockvar *et al*., 2001).

Educating and training healthcare providers is another key approach to improve patient safety and reduce medication errors. Healthcare practitioners, particularly pharmacists and pharmacy technicians continually update their knowledge of drugs. Another approach is the use of 'tall man letter' to differentiate 'look-alike sound like medication' which is commonly applied in hospitals (Gabriele, 2006).

Improving the work environment can reduce fatigue of the healthcare staff and promote safe medication use. There are five key areas that hospitals need to focus on to improve medication use: illumination, interruptions and distractions, sound and noise, physical design and organization of workspace and medication safety zones (Grissinger, 2012). Building a safety culture by encouraging internal risk transparency, coaching and counselling of staff, and avoiding negative retribution for errors are other solutions to prevent medication errors (Weber, 2017).

Although the above approaches can be used to reduce medication errors, the root causes of the problems can still remain in the process. Medication errors are system problems which require the proper system redesign or change (Crane and Crane, 2006). Several experts argue that errors occurring in hospitals usually result from a system error, and even the remaining errors can be avoided if the system is organized to prevent errors (Meadows, 2003; Reiling *et al*., 2003; Nielsen *et al*., 2004). Moreover, research indicates that prevention strategies targeting systems rather than individuals have been considered as the most effective in reducing medication errors (Wilson *et al*., 2005). Therefore, healthcare practitioners can ascertain the problems in the medication process and identify and eliminate the root cause of such problems through the use of LSS.

2.5 LSS roadmap in healthcare sectors – a review of literature

A roadmap helps the healthcare practitioners to understand and follow the steps for implementing LSS projects in a hospital setting (Antony *et al*., 2016). It can guide healthcare organizations in the successful implementation of LSS. Very limited existing literatures proposes a roadmap for deployment of LSS in the healthcare context. Similarly, Nonthaleerak and Hendry (2007) mentioned that few published papers have proposed a practical implementation of LSS roadmap in a service context. Antony and Kumar (2012) pointed out that hospitals do not have a roadmap to sustain LSS. Therefore, a critical review was carried out to determine what was available in terms of frameworks or roadmaps of Lean, Six Sigma and LSS which have been suggested for healthcare

sectors. This review has led to an understanding of key characteristics, limitations, and reasons behind the development of such frameworks and roadmaps.

Yeh *et al*. (2011) and Cheng and Chang (2012) proposed a framework of DMAIC methodology to improve the medication process and to increase the efficiency of resource management in physical disabilities services. These frameworks provided the details in each phase of the DMAIC methodology, along with a limited description of strategic issues such as top management support and leadership to facilitate the implementation of LSS. Similarly, Furterer (2014) provided a roadmap for applying LSS and its tools and techniques in the healthcare processes. This LSS roadmap outlines each phase of DMAIC methodology but is without an explanation of the critical factors for successful deployment of LSS. Subsequently, Honda *et al.* (2018) systematically reviewed the existing frameworks of LSS implementation in the healthcare sectors. The results show that most of the included studies used DMAIC methodology as a framework for implementing LSS. Then, Al-Qatawneh *et al.* (2019) proposed a framework for applying Six Sigma in the areas of healthcare logistics. Al-Qatawneh's study also used DMAIC methodology as a framework and explained the phases of the methodology. The proposed framework was further applied by a private hospital in Jordan which resulted in an improvement in the warehousing process.

Almutairi *et al.* (2019) suggested a framework for implementing the Lean principle in the supply chain management in Saudi healthcare organizations. This framework could assist healthcare practitioners to implement Lean successfully in hospital supply chain management practices. However, this framework is limited to Saudi Arabian settings.

Most of the frameworks are based on DMAIC methodology which is useful for reducing medication errors; however, these frameworks will not change the culture of the hospitals. Several aspects of such frameworks are omitted such as communicating the need for LSS in hospitals, training in relation to LSS tools, the training curriculum, and project selection.

Table 2.12 summarises the key features of frameworks/roadmaps, the methodology used, aim, limitations of the LSS frameworks/roadmaps as promoted by several researchers. The key findings regarding the proposed frameworks/roadmap are summarised as follows.

- Most of the existing frameworks used DMAIC methodology as the LSS framework.

- Most of the frameworks are developed based on the existing literature.
- There were limited frameworks/roadmaps that have been developed based on empirical studies such as surveys and case studies.
- There was limited discussion on the culture of healthcare organizations and strategic issues such as management commitment and resource planning.
- Lack of empirical evidence in the verification of existing roadmaps for LSS in the healthcare context.
- No framework/roadmap identified in the current literature focuses on how to sustain LSS across the healthcare organization

Table 2.12 The key features of each LSS framework/roadmap proposed in healthcare

Framework no.	Authors, year	Methodology used	Aim of LSS frameworks/roadmap	Limitations of the frameworks/roadmap
1	Yeh *et al.* (2011)	Not mentioned	To implement the framework for improving the medical process of acute myocardial infarction	Use of DMAIC as a framework Lack of management focus discussion No validation of the framework by healthcare practitioners
2	Cheng and Chang (2012)	Not mentioned	To implement an LSS framework in non-profit organizations	Use of DMAIC as a framework and lack of strategic focus No verification of the framework by healthcare practitioners
3	Furtherer (2014)	Not mentioned	To apply the roadmap and the key tools in healthcare processes	The roadmap focuses on DMAIC methodology without consideration of strategic issues. No verification of framework by healthcare practitioners
4	Honda *et al.* (2018)	A systematic review of existing frameworks implemented in hospitals	To improve the hospital performance	No explanation or any details related to the framework Use of DMAIC as a framework No verification of the framework by healthcare practitioners
5	Al-Qatawneh *et al*. (2019)	Literature review	To implement a proposed framework in the area of healthcare logistics	Use of DMAIC as a framework

			To present a case study on the implementation of the proposed framework in a Jordanian Hospital	No discussion on strategic issues such as leadership, top management support and resources planning No verification of the framework by healthcare practitioners
6	Almutairi *et al.* (2019)	Literature review and case study	To propose a new framework and for implementing Lean in hospital supply chain management in Saudi settings	There is a limited explanation of Lean tools. The framework is limited to healthcare organizations in Saudi Arabia.

Source: adapted from Kumar *et al.* (2011) and Raval and Kant (2017)

Each framework/roadmap was further evaluated based on the different key characteristics adopted from Nonthaleerak and Hendry (2007) (Table 2.13). Most of them have used DMAIC as a framework, explaining the steps of work in each phase and suggesting tools to be used in the DMAIC methodology. None of the frameworks have been verified by LSS experts or healthcare practitioners. The roadmap proposed in this current research addresses such limitations explained above.

Table 2.13 The key characteristics of each framework/roadmap

Roadmap characteristics	**Yeh *et al.* (2011)**	**Cheng and Chang (2012)**	**Furtherer (2014)**	**Honda *et al.* (2018)**	**Al-Qatawneh *et al.* (2019)**	**Almutairi *et al.* 2019**	**The researcher's roadmap**
Identify objective of each phase		✓	✓		✓	✓	✓
Present as diagram or flow chart	✓	✓				✓	✓
Explain steps for each phase	✓	✓	✓			✓	✓
Verified by healthcare practitioners					✓	✓	✓
Verified by LSS experts							✓
Identify tools and explanation in the road map	✓	✓	✓			✓	✓
Management focus							✓
Using DMAIC as a framework	✓	✓	✓	✓			

Source: adapted from Nonthaleerak and Hendry (2007)

2.6 Systematic Literature Review

There are different types of literature review that a researcher can pursue. It could be, for example, a narrative or traditional literature review, systematic review, or a critical review. The researcher decided to conduct a systematic review because it allows a systematic search and selection of relevant studies to be undertaken to answer the research question. Moreover, the systematic review methodology provides comprehensive results for the research with regards to the research question "What is the current status (challenges, benefits, and success factors) in the use of Lean Six Sigma to reduce medication errors in a global context?" This research question and systematic review helped the researcher to implement LSS successfully in both hospitals by understanding its benefits, challenges and success factors of LSS before entering the inpatient pharmacy. The researcher conducted a systematic review of existing literature to collect relevant empirical studies published in subject-specific journals and key academic databases from 1997-2018. The following sections describe an overview of a systematic review, examine how it differs from traditional reviews and explain the development of systematic review from the past until present.

2.6.1 What is a Systematic Review?

Systematic Review is "a specific methodology that locates existing studies, selects and evaluates contributions, analyses and synthesizes data, and reports the evidence in such a way that allows reasonably clear conclusions to be reached about what is and is not known" (Denyer and Tranfield, 2011, p.671). The predominant characteristics of systematic reviews are that they are replicable, a scientific investigation, and they offer a transparent approach (Cook *et al*., 1997; Denyer ande Tranfield, 2011). The researcher is required to identify the eligibility criteria that is inclusion and exclusion for studies, through a clear process (Denyer and Tranfield, 2011). It means that the process of locating, selecting, appraising and synthesising relevant evidence should be obvious for the readers, to minimize bias in including the studies. Systematic reviews are valuable when there is uncertainty about the answer to key questions and when ascertaining the effectiveness of particular interventions (Petticrew and Roberts, 2006). The next section demonstrates how a systematic review differs from traditional reviews.

2.6.2 The difference between Systematic and Traditional Review

Systematic reviews adopt a particular methodology for evaluating research evidence (Victor, 2008). They differ from the traditional review in that they seek to minimize bias and errors when searching published and unpublished studies (Cook *et al*., 1997). A traditional review summarises and discusses the current knowledge in a particular field and addresses a wide range of problems. Conversely, a systematic review is conducted to answer specific research questions and test hypotheses and it assesses the quality, including the validity and reliability, usually of interventions and controlled studies (Cook *et al*., 1997; Petticrew and Roberts, 2006). The differences between the traditional review and systematic review are summarised in Table 2.14.

Durach *et al.* (2017), based on the study of Cooper (2010) highlighted four key biases: sampling bias; selection bias; within-study bias; and expectancy bias when conducting systematic literature reviews. They further identified the solutions to clarify these potential biases, for example, involving expert researchers when searching for studies, and using multiple researchers to code and synthesise studies.

Table 2.14 The comparison between a traditional and systematic review.

	Traditional review	**Systematic review**
Aim	To gain a broad understanding and description of the field	Specific aim and objectives with a specific research question
Scope	Big picture	Narrow focus
Planning the review	No defined path allows for creativity and exploraton	Transparent process
Identifying studies	Searching is probing, moving from one study to another, following up leads	Rigorous and comprehensive search for all studies
Selection of studies	Purposive selection made by reviewer	Predetermined criteria for including and excluding studies
Quality assessment	Reviewer's opinion	Checklists to assess the methodological quality of studies
Analysis and synthesis	Discursive	Tabula format and a short summary
Methodological report	Not necessarily given	Transparency

Source: Jesson *et al.* (2011)

2.6.3 The past, present, and future of Systematic Reviews

Systematic reviews have been produced in healthcare since the early 1980s (Petticrew and Roberts, 2006). In 1992, the Cochrane Collaboration, an international initiative, was established to select, evaluate, and disseminate research evidence and developed guidelines to conduct systematic reviews in the medical field (Denyer and Tranfield, 2011). Since then, the systematic review has been followed by researchers who seek to improve the rigour and reliability of the review process and also to organize knowledge in a way that is useful (Denyer and Tranfield, 2011). In 2000, the Campbell Collaboration, a sister initiative of the Cochrane Collaboration, was formed to produce the systematic review of research evidence on the effectiveness of social interventions (Campbell Colloboration, 2017). Furthermore, Tranfield *et al.* (2003) applied an adaptation of the systematic review methodology used in medical sciences to the management field. The study of Tranfield *et al.* (2003) has been widely cited in many research studies as a guideline for conducting systematic reviews in management. However, Armitage and Keeble-Allen (2008) conducted semi-structured interviews within four case studies and argued that the study of Tranfield *et al.* (2003) was not appropriate to apply to small scale research projects, but was more suitable for other types of research such as doctoral level and policy-based activities.

In the social sciences, Victor (2008) proposed three primary approaches for conducting a systematic review: traditional, extended and/or adapted, and integrative. The traditional method has been designed to question concerns about the measurement of outcomes of social policy programmes. An extended or adapted traditional approach has been used to answer broad questions, whilst an integrative approach aims to test and build theory through the review. Victor (2008) further mentioned that in the social sciences, the literature and debates on systematic literature reviews are increasing, and the method is being continuously developed.

There is limited literature that critically reviews Lean and Six Sigma methodologies in the context of medication errors as there are only two studies, conducted by Glasgow et al. (2010) and Mason et al. (2015), that have systematically reviewed the application of LSS in healthcare sectors. This research systematically reviewed the Lean, Six Sigma, Lean Six Sigma (LSS) interventions and the use of tools and techniques in hospitals' efforts to improve patient safety and reduce medication error frequency and severity. The

methodology for conducting the systematic review and key findings is explained in the following sections.

2.7 Systematic Literature Review of LSS in reducing medication errors: Key findings

Two studies have been conducted regarding the use of LSS in healthcare sectors. Glasgow *et al.* (2010) systematically assessed the literature on LSS in the acute care setting and another study carried out by Mason *et al.* (2015) focused on the use of LSS in surgery. No systematic reviews of the use of Lean, Six Sigma and LSS to reduce medication errors have been reported in the current literature, and thus this research could bridge the gap. Four stages for conducting a systematic review have been developed and these are explained in the next section.

2.7.1 Methodology

A systematic review was conducted to find the relevant articles by following four main steps: (1) ascertain the inclusion and exclusion criteria; (2) identify the sources of information used to collect the articles and search strategy; (3) describe the study selection process; and (4) specify the data extraction process. These four steps have also been found in previous systematic literature review studies such as Balaid *et al.*(2016), Burns *et al.* (2016), and Teo *et al.* (2016). The following steps have been used in the systematic literature review methodology.

(1) Eligibility criteria

The eligibility criteria are identified to ensure that the included articles are relevant to the study (Balaid *et al*., 2016). In this review, inclusion criteria included academic articles in peer-reviewed journals published in English between January 1997 and December 2018. The search for journals and key databases demonstrated that there were no research articles related to LSS and its tools and techniques before 1997 (Albliwi *et al*., 2015). Articles were included when they discussed the implementation of Lean, Six Sigma, LSS and its tools and techniques to reduce medication errors or improve medication management. In contrast, exclusion criteria included grey literature such as books, magazines, conference papers, white papers, editorials, etc. Studies published in all languages other than English, published before January 1997 were also excluded. The review studies that discussed other methodologies, e.g. CI such as total quality

management (TQM), Kaizen, technology to reduce medication errors, improvements in medication management and reconciliation.

(2) Information sources and search strategy

The articles were initially retrieved through subject-specific journals and key academic databases. Subject-specific journals were identified based on the top journal ranking lists in the Business School and Healthcare sectors. Primary databases used included *Medline, PubMed, EBSCOhost, Web of Knowledge, Scopus, Embase, CINAHL and PsycINFO*. These eight academic databases were selected because they provided relevant journal articles covering several fields of study such as Biomedicine, Health, Pharmacological, Social Science, and Natural Science. The search strategy began with the identification of keywords, search strings and applying search intervention in the selected databases. The following search strings: 'Lean AND Medication Error' 'Six Sigma AND Medication Error' 'Lean Six Sigma AND Medication Errors' 'Tool and Technique AND Medication Error' 'Quality Tool AND Medication Error' and 'Quality Technique AND Medication Error' were applied to search all of the relevant articles from the selected journals and aforementioned databases.

(3) Study selection process

Figure 2.3 presents the selection process for the study. In each step, the number of included and excluded studies are documented with explanations for the exclusion (Tranfield, *et al.*, 2003). A total of 5,369 articles were initially retrieved from searching the databases and an additional two articles from the subject-specific journals. The researcher screened the titles and abstracts by applying the inclusion and exclusion criteria (Ozawa and Sripad, 2013). Duplicate studies and articles subject to the exclusion criteria were discarded at this stage. The remaining 42 full-text articles were carefully reviewed based on the inclusion and exclusion criteria. A total of sixteen articles were excluded because they discussed methodologies other than Lean, Six Sigma, LSS, and its tools and techniques. Finally, 26 final articles were selected for the inclusion in the study for further analysis.

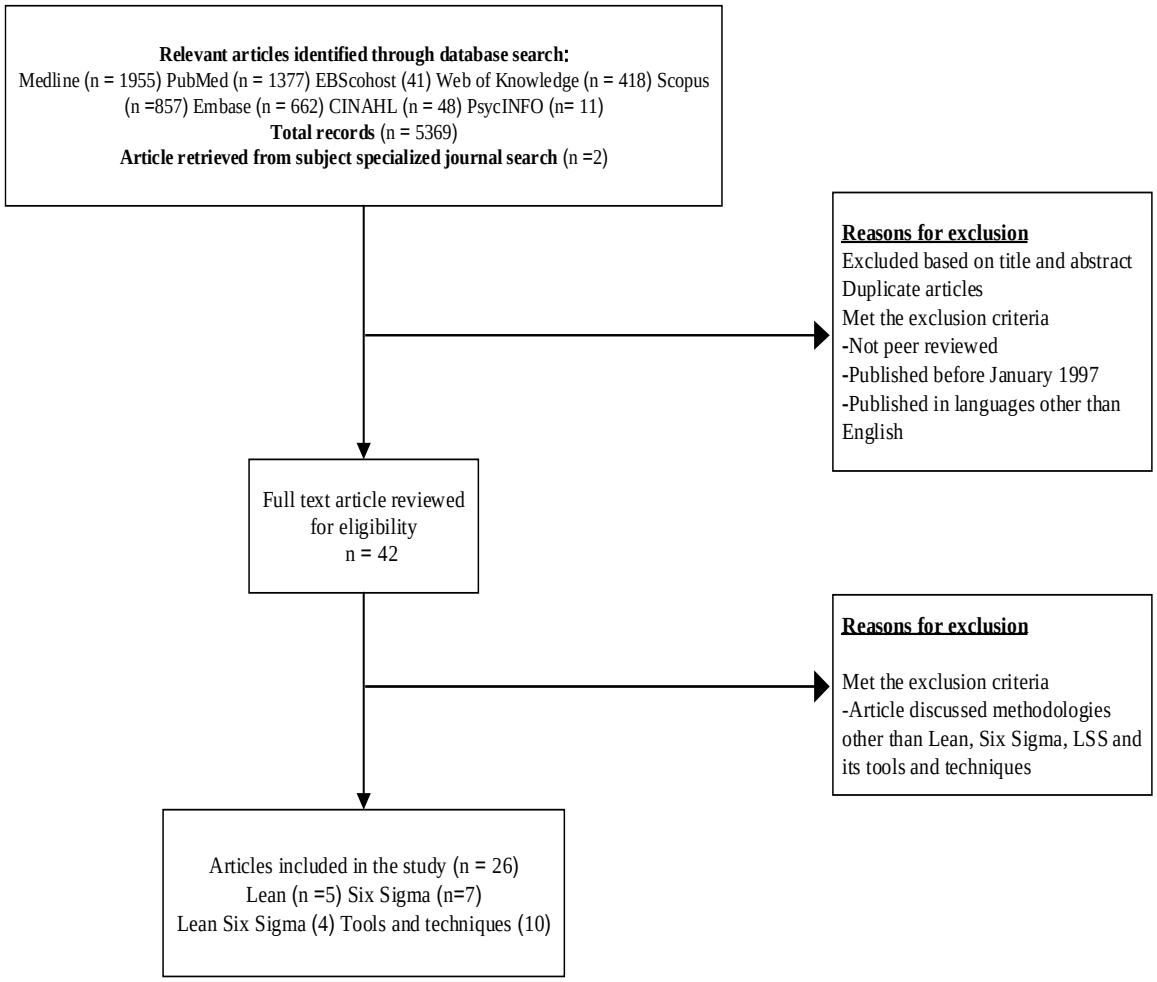

Figure 2.3 Study selection process

(4) Data Extraction

The data from the included articles were extracted and stored on the data extraction form to reduce human error and bias (Tranfield *et al*., 2003). The researcher reviewed each article and carefully placed the data into MS Excel spreadsheets (Balaid *et al*., 2016). The extracted data included year of publication, journal and article title, objective, type of study, authors' country, tools and techniques used, key findings, benefits, challenges and success factors. Finally, the included studies are represented in the form of table providing a summary and visual presentation of the studies (Denyer and Tranfield, 2011).

2.7.2 Key findings

Several themes emerged from the analysis of included studies including: publication trend, country distribution, tools and techniques of Lean and Six Sigma in the context of medication errors, Lean and Six Sigma methodologies, types of medication errors, benefits, challenges and critical success factors. The researcher applied thematic analysis

by using a manual approach to code the units of data, and finally different themes were generated.

A. Publication trend

The study shows the publication trend of Lean, Six Sigma, LSS and its tools and techniques implementation in the healthcare sector to reduce medication errors and improve medication management. As shown in Figure 2.4, a study by McNally *et al.* (1997) used failure mode and effect analysis (FMEA) to eliminate possible medication errors in a ward stock drug distribution system in an Australian hospital. It is interesting to note that, in 2004, Six Sigma was first applied to reduce dispensing errors in a pharmacy department in Taiwan (Chan, 2004). The following year LSS was implemented to reduce medication order entry errors in a US mid-sized hospital (Esimai, 2005) while Lean was first implemented to reduce missing dose incidents in 2009 in a university hospital inpatient pharmacy (Hintzen *et al*., 2009).

In 2015, four papers were published about the reduction in medication errors. A study by Critchley (2015) used Lean methodology to improve medication administration safety in a community hospital in Canada, while Rodriguez-Gonzalez *et al.* (2015) used FMEA to improve the medication administration process in a hospital setting in Spain. Hussain *et al.* (2015) recommended the implementation of the Toyota Production System (TPS), combined with human performance improvement (HPI), to eliminate medication errors in the hospitals. However, Luton *et al.* (2015) used Lean and Six Sigma methodology to reduce the occurrence of errors in the preparation, dispensing, and administration of human milk and formula. Although few studies were published between 2003 and 2018, the trend shows an increase between the selected periods.

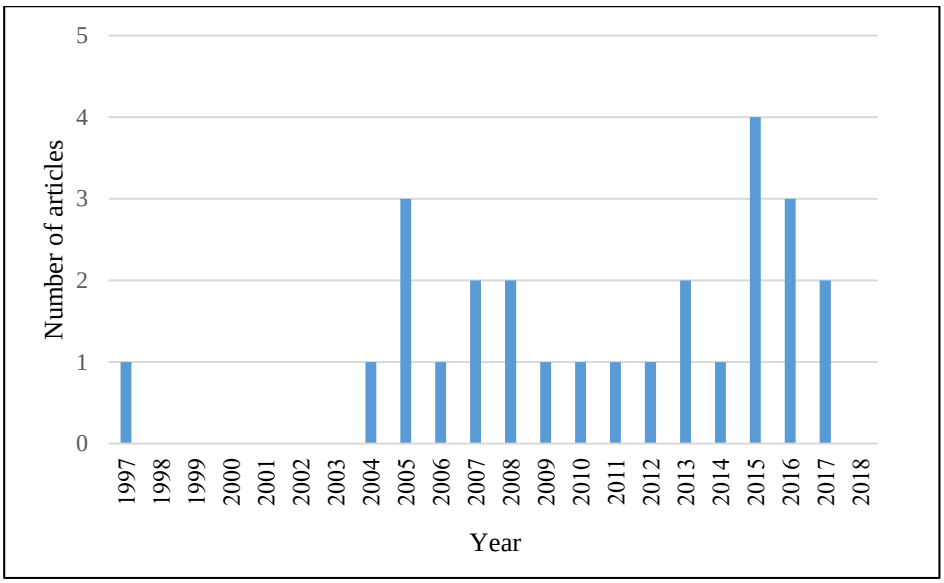

Figure 2.4 Trend of publication between 1997 and 2018

B. Country distribution

The country of the selected studies was classified according to the origin of the first author of the articles. Figure 2.5 shows that the USA has the highest number of publications, which accounts for 60% compared with other countries. Spain is second in term of number of publications with three articles which employed FMEA to reduce medication errors in the medication process. The other countries - England, Iran, Taiwan, Italy, Canada, Australia, Syria, and Saudi Arabia - have published one article each on the search topic.

The study demonstrates that the USA is the leading country reporting Lean, Six Sigma and LSS implementation to eliminate medication errors in hospitals. In Asia, a study conducted in Taiwan by Chan (2004) shows improvement in pharmacist dispensing errors at an outpatient clinic through the implementation of Six Sigma. In other Asian countries such as Thailand, Malaysia, and Indonesia, there is a lack of data on medication errors, resources and government support (Salmasi *et al*., 2015) which may lead to the limited research on medication errors in the Asian countries. The review also found that a study by Critchley (2015) from Canada was the only published research using Lean methodology to improve medication administration safety in a community hospital; Whereas other countries mostly focused on FMEA adoption to reduce possible medication errors in the medication process.

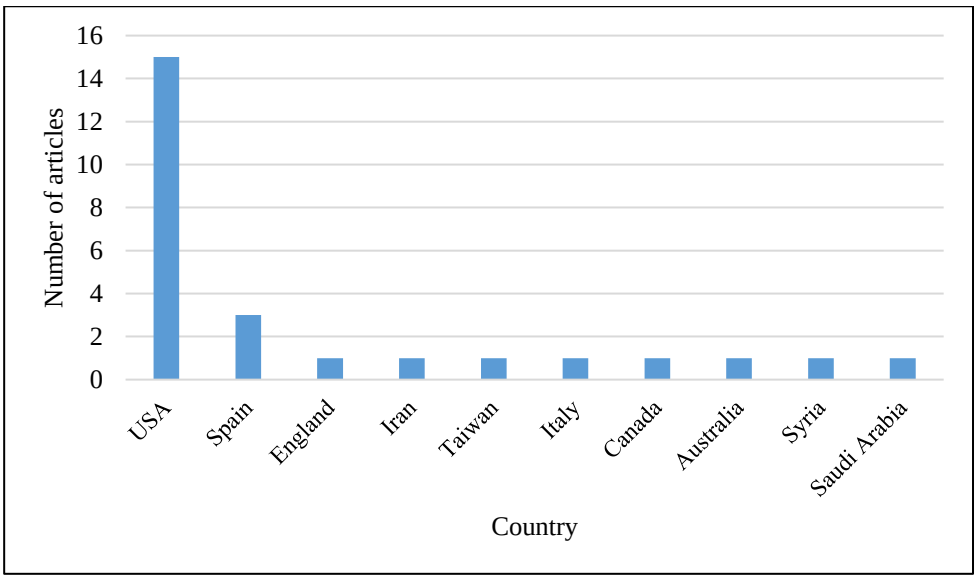

Figure 2.5 Selected study distribution based on country of publication

C. Tools and techniques of LSS in the context of medication error

From the reviewed articles, 22 Lean tools which were aimed at reducing errors in the medication process were identified. These included process mapping, brainstorming, Voice of the Customer (VOC), standardised operating procedures, Poka-yoke, cause and effect diagram, Value Stream Mapping (VSM), just in time (JIT), process observation and analysis, time and motion study, work cell optimisation, visual process controls, workplace inspection, 5 why root cause analysis, A3 problem solving report, one-piece flow, Kanban, spaghetti diagram, bird's eye view maps, 5S practice, standardised weekly audit and two bin replenishment.

Figure 2.6 shows the top five Lean tools which are widely used to reduce medication errors. It is interesting to highlight that process mapping is the most popular Lean tool to reduce such errors because it visually represents the process steps and helps to identify the potential errors in the medication delivery process, while value stream mapping represents all important flow of information and materials throughout the complete medication process. Process mapping tools can help healthcare practitioners to understand the current problems in the medication process such as poor flow, rework loops and delays. Standard operating procedure is a step-by-step set of instructions helping healthcare practitioners to perform the work correctly such as standardizing pharmacy order entry process (Critchley, 2015) and standardizing nursing work (Ching *et al*., 2013). Visual process control is used to create a transparent environment by using several displays and visual markers (George *et al*., 2005) such as a no-talking zone sign in the medication room (Ching *et al*., 2013) and a colour-coded bin system in the

inventory areas (Hintzen *et al*., 2009). Poka-yoke or mistake proofing reduces errors by the use of any devices or methods (George *et al*., 2005) and stops an error before passing to another phase of the work. Some examples of mistake proofing devices which have been used to avoid medication errors include using an automatic dispensing machine (Chan, 2004), barcoding (Chiarini, 2012) and requiring an online medication ordering system (Kumar and Steinebach, 2008).

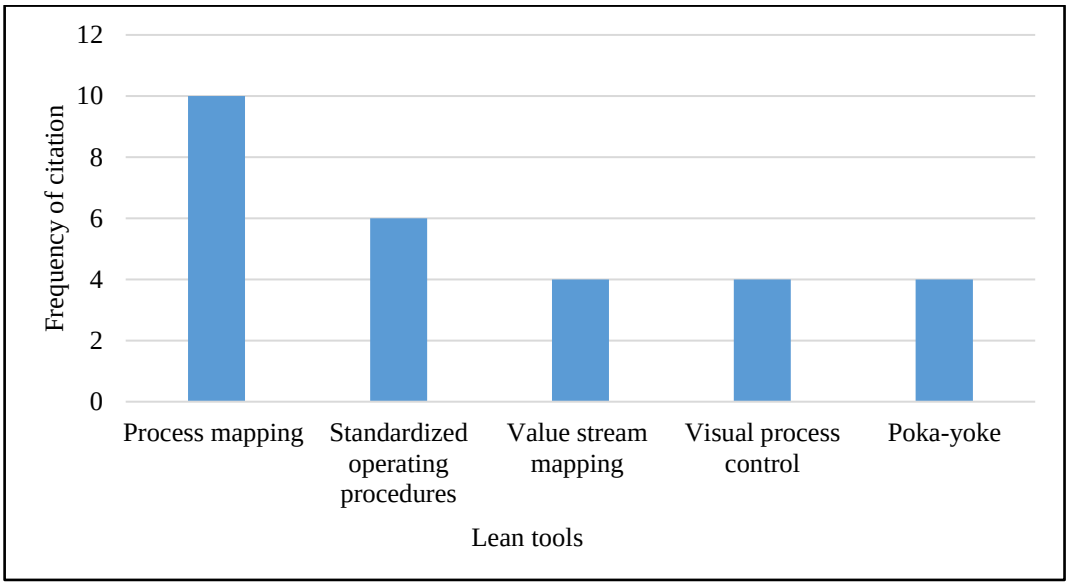

Figure 2.6 Top five Lean tools used to reduce medication errors

Six Sigma tools and techniques were identified by eight studies (Table 2.15). In the define phase, VOC and problem definition tools were used to determine what customer (nurses, pharmacists and patients) need, and to identify problems leading to error in the medication process (Chan, 2004; Hintzen *et al*., 2009). Next, the measure phase, data collection and analysis and baseline measurement, were used to ascertain the baseline performance evidence-base, showing the current state of the problem (Chan, 2004; Kumar and Steinebach, 2008; Yousef and Yousef, 2017). For example, in the outpatient pharmacy, a data collection sheet was used to collect the baseline data and to identify which type of medication errors were occurring and during which process steps (Al Kuwaiti, 2016). Subsequently, the root causes of the problems that contribute to the occurrence of the medication errors were identified in the analyse phase. The common tools used in this phase include staff brainstorming, cause and effect analysis and process mapping (Chan, 2004; Castle *et al*., 2005; Kumar and Steinebach, 2008). The next phase was the improve phase, which aimed to identify and implement solutions to eliminate the root causes of the problems, for examples, creating a procedure to enhance sound-alike/look-alike (SALA) alert, providing an ongoing education and training for the pharmacist for each of

the selected root causes in order to improve the process performance (Castle *et al*., 2005). The common tool used in this phase is poka-yoke and includes CPOE, automated dispensing system and barcoding. Finally, in order to control the sustainability of process performance, control chart and run chart were used to sustain the reduction of medication errors over a period of time (Kumar and Steinebach, 2008; Al Kuwaiti, 2016).

Moreover, the tools and techniques of LSS are used across the medication process including prescribing, transcribing, dispensing and administration, as shown in Table 2.16. FMEA is a Six Sigma tool used in every stage of the medication process, because it could identify the potential of medication errors in every phase of the process. Other tools and techniques such as process mapping and data collection and analysis are used in the prescribing and dispensing phases. However, in the transcribing phase, FMEA is a single tool used to reduce errors because of the limitations of the literature.

Table 2.15 Lean Six Sigma tools used in various phases of DMAIC methodology

Study title	Define	Measure	Analyse	Improve	Control
Lean Six Sigma reduces medication errors (Esimai, 2005).	Problem definition Project charter Process mapping	Data collection and analysis Pareto chart	Brainstorming	Brainstorming Standardized operating procedures	Simple linear regression analysis
Hospital reduces medication errors using DMAIC and QFD (Benitez *et al*., 2007).	Not mentioned	Process mapping	Brainstorming	QFD Pugh Selection Matrix VOC	Control chart
Use of six sigma to improve pharmacist dispensing errors at an outpatient clinic (Chan, 2004).	Review historical data	Baseline measurement Data collection and analysis	Process mapping	Poka-yoke	Control chart Run chart
Using Six Sigma to reduce medication errors in a Home - Delivery Pharmacy Service (Castle *et al*., 2005).	Process mapping	Data collection and analysis	Brainstorming Process control plan	Poka-yoke Linear regression analysis	Control chart
Applying Lean Six Sigma to improve medication management (Nayar *et al*., 2016)	Process mapping	Data collection and analysis	Brainstorming	Brainstorming	Brainstorming
Using total quality management approach to improve patient safety by preventing medication error incidences (Yousef and Yousef, 2017)	Problem definition	SIPOC VOC	Cause and effect analysis Pareto chart	Brainstorming	SOP
Application of Six Sigma methodology to reduce medication errors in the outpatient pharmacy unit (Al Kuwaiti, 2016)	SIPOC VOC CTQ	Data collection and analysis	FMEA Pareto chart	Brainstorming Poka-yoke 5S	Poka-yoke
Experiences with Lean Six Sigma as improvement strategy to reduce parenteral medication administration errors and associated potential risk of harm (van de Plas *et al*., 2017)	Problem definition	Baseline measurement VSM	Cause and effect analysis 5 Why analysis	Brainstorming	Not mentioned

Table 2.16 Lean Six Sigma tools and techniques used in the medication process.

Medication process	Lean Six Sigma tools and techniques	References
Prescribing	Process mapping Cause and effect analysis Poka-yoke FMEA Data collection and analysis Linear regression analysis Control chart Process control plan Brainstorming SIPOC VOC CTQ Pareto chart 5S SOP	Castle *et al.* (2005); Kunac and Reith, (2005); Lago *et al.* (2012); Vélez-Díaz-Pallarés *et al.* (2013); Al Kuwaiti (2016); Yousef and Yousef (2017)
Transcribing	FMEA	Arenas Villafranca *et al.* (2014)
Dispensing	Process mapping Data collection and analysis Linear regression analysis Control chart Process control plan Brainstorming Review historical data VOC Baseline measurement Poka-yoke Run chart FMEA	Chan (2004); Castle *et al.* (2005); Vélez-Díaz-Pallarés *et al.* (2013); Arenas Villafranca *et al.* (2014)
Administration	Value Stream Mapping Just in time Process observation and analysis Time and motion study Work cell optimization Visual process control Workplace inspection t-test Chi-square Linear and logistic regression analysis FMEA 5 why root cause analysis A3 problem solving report Project team charter SIPOC Spaghetti diagram Bird's eye view maps Standard operating procedures Cause and effect analysis Run chart 5 S	Kunac and Reith (2005); Riehle *et al.* (2008); Ashey *et al.* (2011); Lago *et al.* (2012); Ching *et al.* (2013); Rodriguez-Gonzalez *et al.* (2015); van de Plas *et al.* (2017).

D. Lean and Six Sigma methodologies

The researcher observed from the analysis of current literature that only eight selected studies have implemented DMAIC methodology to reduce medication errors in different categories. Esimai (2005) and Benitez *et al*. (2007) followed the DMAIC methodology to improve the order medication entry process. Benitez *et al.* (2007) revealed that, during the improve phase, DFSS is implemented to design one standard medication order process which can be used in whole hospital units except an emergency unit. As a result of DFSS initiatives, the chronological sheet from all patient charts is replaced by the existing patient care activity record (PCAR). After the process change, the percentage of order entry accuracy improved by 90% to less than 0.04 errors per bed every month for four months. Chan (2004) and Al Kuwaiti (2016) followed the DMAIC methodology to improve the dispensing process and achieve operational goals; as a result, dispensing errors were reduced by 30% and 10%, respectively. A study by Castle *et al.* (2005) used DMAIC methodology to reduce several types of medication errors including wrong drug selection, wrong direction and look-alike/sound-alike errors in a home-delivery pharmacy service. A case study conducted by Nayar *et al.* (2016) used the DMAIC process step to improve medication management of dual care veteran patients.

The Lean methodology includes five key principles: define value; define value stream; create flow; establish pull based on customer requirement; and seek perfection (Carlborg *et al*., 2013). This study found that of the selected studies most use only Lean tools to reduce medication errors. However, the study conducted by Critchley (2015) implemented a Lean methodology to improve medication administration safety in a community hospital in Canada.

E. Types of medication errors

The review of the literature indicated that administration error is the most dominant type of medication error, as shown in Figure 2.7. This demonstrates that errors occurring in the administration phase need to be greatly reduced, followed by reduction in dispensing, preparation and prescription errors. The study also found that administration errors are the area where Lean thinking and FMEA have most been used to reduce errors, while Six Sigma is commonly used to reduce dispensing errors in the pharmacy department.

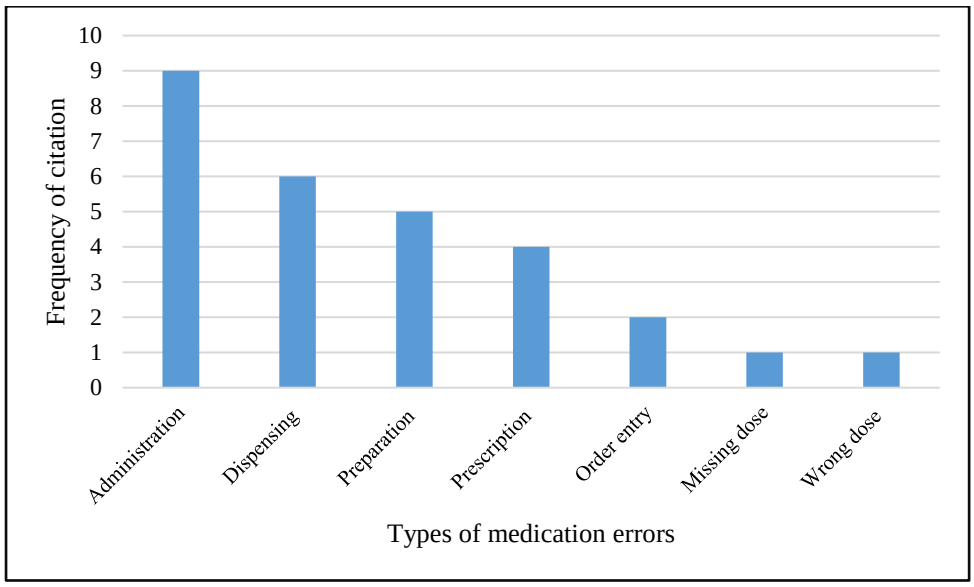

Figure 2.7 Types of medication errors.

F. Benefits

- *Benefits of Lean*

The key benefits of Lean are reductions in medication errors and wastage of expired medications, improvement of workflow, reduction of waste and improvement of the medication process and room layout (Printezis and Gopalakrishnan, 2007; Critchley, 2015; Hussain *et al*., 2015). These benefits can contribute to cost savings, improve patient safety, decrease many injuries and death and enhance staff and physician satisfaction. One study reported that the implementation of Lean in the sterile product area (SPA) and inventory area at the university hospital inpatient pharmacy could save $289,256 annually due to the reduction of waste and improvement in staff workflow (Hintzen *et al.*, 2009). After the implementation of Lean process improvements, the number of production errors such as incorrect labelling in the SPA decreased by 83% and the average number of missing intravenous doses reduced from 53 to 13.8 per day (Hintzen *et al*., 2009). Moreover, the employment of Lean can also improve medication administration safety by reducing the rate of serious medication harmful events in the hospital (Critchley, 2015).

- *Benefits of Six Sigma and Lean Six Sigma*

The primary benefit of Six Sigma methodology is the reduction in the number of errors in different phases of the medication process, particularly in the dispensing and administration phases. For example, Six Sigma was implemented by Chan (2004) to reduce dispensing errors in Taiwanese pharmacy department by 30%. Another study

showed that the percentage of order entry errors consistently improved by 90% to achieve less than 0.04 errors per bed every month for four months after deployment of Six Sigma (Benitez *et al*., 2007). The application of Six Sigma in a medication home-delivery service resulted in an improvement in the data collection process and the reduction of several types of medication errors (Castle *et al*., 2005). Two studies followed the DMAIC methodology providing a noticeable result in the reduction of errors relating to administered medication doses and parenteral medication administration (van de Plas *et al*., 2017; Yousef and Yousef, 2017). Moreover, the implementation of Six Sigma not only reduced medication errors, but also improved staff working performance, patient safety, and satisfaction and hospital profitability (Chan, 2004).

- *Benefits of FMEA*

FMEA has its own benefits such as reduction of medication errors in the prescribing, preparation, validation, dispensing and administration process (Arenas Villafranca *et al*., 2014; Lago *et al*., 2012; Rodriguez-Gonzalez *et al*., 2015; Sheridan-Leos *et al*., 2006). Another benefit of FMEA is the improvement of safety in the medication preparation process (Aboumatar *et al*., 2010), prescription process (Kunac and Reith, 2005) administration process (Riehle *et al*., 2008; Rodriguez-Gonzalez *et al*., 2015) and drug delivery process (Lago *et al*., 2012).

G. Challenges

The challenges of LSS identified from a thorough review of the literature include: lack of top management support and availability of data. A study conducted in a Government Hospital showed a lack of medication error reporting and no registration system of any related data (Yousef and Yousef, 2017). Moreover, a team implementing a Six Sigma project to reduce medication errors in a home-delivery pharmacy service also encountered many impediments in the early phase (Castle *et al*., 2005). First, it was difficult to gain agreement to make changes in the process, with a noted lack of senior management buy-in. Second, there were variations among pharmacies in the data collection processes, which contributed to contradictory medication error reporting and, finally, there was a lack of knowledge about data collection tools.

Four researchers further report the challenge of FMEA implementation to reduce errors in the medication process. The major challenge of FMEA adoption is that it is a costly and time-consuming process (Kunac and Reith, 2005; Sheridan-Leos *et al*., 2006; Ashey

et al., 2011). Also, it can be challenging for those who are inexperienced (Sheridan-Leos *et al*., 2006). Although FMEA can be considered as of great value, there is little evidence to support that it can be used for quantitative prioritization of the failures of the process because it lacks both reliability and validity (Vélez-Díaz-Pallarés *et al*., 2013).

H. Critical Success Factors

Critical success factors are important to the successful implementation of any quality improvement initiates (Desai *et al*., 2012). It can help people to understand what factors are important for making LSS successful and what factors are not important to the success (Antony and Banuelas, 2002). Seven success factors were extracted from LSS implementation to reduce medication errors including: a) understanding of LSS tools and techniques and its philosophy; b) top management support; c) training; d) staff engagement; e) leadership capability; f) appropriate team formation or implementation infrastructure; and g) cultural change.

Understanding Lean and Six Sigma tools and techniques and their philosophy by staff at all levels in healthcare organizations, in particular, those involved at the sharp end of care processes in the medication process plays an important role in effective Lean and Six Sigma implementation (Chan, 2004; Hintzen *et al*., 2009). A clear vision from the top management and support for dedicated offline resources by senior administration are critical factors leading to the success of LSS projects (Hintzen *et al*., 2009; Ching *et al*., 2013). The LSS initiative will be difficult without top management support and commitment (Pande *et al*., 2000). Training is another significant factor leading to successful projects. The core team of a Six Sigma project received training as accredited Green or Black Belts while the executive staff or project sponsor trained as Yellow Belts (Hintzen *et al*., 2009). At the same time, a Six Sigma Master Black Belt participated in the DMAIC methodology, providing expert resource information throughout the project (Benitez *et al*., 2007). Moreover, the level of staff engagement in identifying opportunities to improve and implement solutions using Lean tools is a key factor leading to the success of the project. Engaged leadership motivates people in the organization and encourage them to collaborate in order to achieve the business goals in relation to medication error reduction using LSS approaches (Pamfile *et al*., 2012). Identifying appropriate team members is another factor that is necessary for the success of the project. For example, a team member is selected based on the basis of the alignment of their daily responsibility with the project's objective in order to maximize resources (Castle *et al*.,

2005). Embedding LSS into the healthcare culture also results in the success of the project (Luton *et al*., 2015).

It is important to highlight that in the literature, the implementation of FMEA in the context of medication errors has shown its own success factors which include staff engagement, multidisciplinary team, well-communicated plan, use of an FMEA facilitator, leadership sponsor and sufficient resources.

2.8 Limitations of the review

Several limitations have been identified in the review. First, the number of included studies is low due to the inclusion and exclusion criteria. Second, the review may have been influenced by publication bias; unpublished studies on this subject may be more likely to have inconclusive results (Hesselink *et al*., 2012; Balaid., 2016). Finally, a search strategy was limited to English-language studies and did not include unpublished abstracts from conference proceedings or non-indexed journals (Hesselink *et al*., 2012).

2.9 The gaps identified in the literature

The following gaps have been identified from the literature review:

1) The current studies have shown that the application of LSS has focused on process time (e.g. length of stay, waiting time and turnaround time) rather than on addressing medication errors. To make up for this deficit, it is important to assess the status of LSS implementation to reduce medication errors in a global context.

2) The USA is the leading country that reports the highest number of Lean, Six Sigma, LSS and FMEA publications. However, in Europe, a few papers have been published on Lean, Six Sigma and LSS regarding the reduction of medication errors. In Asia, Thailand is far behind the USA and no studies have implemented Lean, Six Sigma or LSS to reduce medication errors. To bridge this gap, the study implemented LSS to reduce dispensing errors in Thai public Hospitals.

3) The literature shows that the reduction of administration errors is the most dominant type targeted by healthcare practitioners, whereas dispensing errors could also cause harm to the patient. Moreover, LSS application is primarily implemented in inpatient care areas such as intensive/critical care, operating room and medication administration. No previous studies have conducted research in the inpatient

pharmacy. To bridge this gap, the study implemented LSS to reduce dispensing errors in the inpatient pharmacy service.

4) The current literature highlights that very few studies use pure Lean, Six Sigma and LSS to reduce medication errors. Previous studies have shown a lack of understanding of how to select and use LSS tools and techniques in each phase of DMAIC methodology. To address this problem, the study used different tools and techniques from LSS toolboxes in each phase of the DMAIC methodology.

5) In healthcare sectors, the research to date has not used action research in reducing medication errors through the implementation of continuous improvement methodology. In order to use an appropriate methodology that combines research and development, the action research was implemented to illustrate the implementation of LSS through collaboration between the researcher and participants.

6) The review reveals that the current literature does not provide a Lean, Six Sigma or LSS road map for healthcare practitioners to follow in order to reduce medication errors in their hospitals. To bridge the gap, an LSS roadmap was developed and verified by LSS experts to guide healthcare practitioners in the implementation of LSS for reducing medication errors, and this is one of the main contributions to knowledge of this study.

2.10 Chapter summary

Medication errors lead to patient mortality and mobility and are costly problems in hospitals. The review reveals that LSS is a powerful process improvement methodology that could be applied to reduce medication errors. The integration of Lean and Sigma tools plays a key role in the improvement of the medication process. Lean tools can be used to enhance the workplace environment, which could reduce excessive workloads of staff, incorrect dosage calculation and miscommunication, whereas Six Sigma tools can be developed to reduce mean errors and even variation in error rate in the medication process.

Several key themes have emerged from a systematic review of existing literature including: tools and techniques of Lean and Six Sigma applied in the context of medication errors, Lean and Six Sigma methodologies, types of medication errors, benefits, challenges, and success factors of LSS implementation in the reduction of

medication errors. The review reveals that there is a noticeable increase in the interest for Lean, Six Sigma and LSS application to reduce medication errors especially in developed countries such as the USA. The review also explored the most significant challenges encountered by hospitals when implementing LSS to reduce errors in the medication process, which include lack of top management support and availability of data. To overcome these challenges, it is important to understand Lean and Six Sigma tools and techniques and their philosophy, to gain support from top management, engage in training, and achieve appropriate team formation or the implementation of suitable infrastructure alongside cultural change.

The rudimentary gaps in the literature on the use of operational excellence methodologies for tackling medication errors and in particular dispensing errors are: 1) no previous studies have been conducted using LSS to reduce dispensing errors in the inpatient pharmacy service; 2) the current literature has shown a lack of understanding in how to select and use Lean and Six Sigma tools and techniques; 3) no previous studies in healthcare sectors have used action research with continuous improvement methodology to reduce medication errors or improve medication process; and 4) there has been no LSS roadmap to guide healthcare practitioner to embark on LSS for addressing medication errors.

CHAPTER 3 – RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter aims to identify the choice of methodology and methods which have been used to address the research questions. The chapter presents the philosophical framework, beginning with a discussion of different types of research paradigms, and then identifies how particular research paradigms are linked to research approaches, methodologies, and methods. Details of data analysis and ethical considerations are presented in the final section of the chapter.

3.2 Research philosophy

Researcher philosophy refers to the beliefs and assumptions about the development of knowledge and the nature of that knowledge (Saunders *et al*., 2016). Understanding research philosophy is essential for researchers because it can shape how researchers formulate problems and research questions to study and how they seek information to answer the questions (Creswell, 2012). Moreover, an awareness of research philosophy can increase the quality of research, and contribute to the creativity (Easterby-Smith *et al*., 2012). The assumptions underpinning philosophical positions include ontological, epistemological and axiological assumptions and these shape how researchers address research questions (Saunders *et al.*, 2016). Each of these is discussed in the next section.

3.3 Philosophical assumptions

3.3.1 Ontological assumptions

The ontological assumption is related to the nature of being and reality (Crotty, 1998; Creswell, 2012). It can inform the way in which researchers study and understand research aspects such as organizations, events, and management (Saunders *et al*., 2016). In adopting a particular ontology, the question should be asked: 'What is the nature of reality?' and 'What is the type of knowledge generated?' by basing the research on these assumptions (Neuman, 2014; Saunders *et al*., 2016). The ontological position of the researcher is that there is an objective reality that exists apart from human experience; however, reality is grounded in the environment and can be encountered through the participants' and the researcher's experience (Goles and Hirschheim, 2000; Teddlie and Tashakkori, 2009).

3.3.2 Epistemological assumptions

The epistemological assumption is concerned with the nature of knowledge, and what is accepted as valid and legitimate knowledge (Crotty, 1998; Bryman and Bell, 2011; Collis and Hussey, 2014). In the context of business and management, different types of knowledge can be ranked from numerical data to textual and visual data, and all of these forms of data can be considered legitimate (Saunders *et al*., 2016). The epistemological assumption assists the researcher to consider which data would be acceptable and which have good quality. The epistemological position of the researcher is that knowledge is based on experiences and can contribute practical solution that inform future practice (Saunders *et al*., 2016).

3.3.3 Axiological assumption

The axiological assumption is concerned with the roles of values and ethics in research (Patton, 2002; Collis and Hussey, 2014). It incorporates questions about how researchers deal with both their own values and those of the participants (Saunders *et al*., 2016). It focuses on the role of the researcher's values in research. The questions should be asked: 'What is the role of value in research' and 'How should the researcher deal with the values of participants' (O'Gorman and MacIntosh, 2015; Saunders *et al*., 2016). In this study, the axiological assumption of the researcher is that the values of the researcher are important in interpreting the results and are free from bias.

3.4 Research paradigms

Developing a research design begins with the identification of a research paradigm. A paradigm is "a framework that guides how research should be conducted, based on people's philosophies and their assumptions about the world and the nature of knowledge" (Collis and Hussey, 2014, p.43). The particular research paradigm will be aligned with the researcher's assumptions, but it will be influenced by the dominant paradigm within certain research areas and the nature of the research problems (Burns and Burns, 2008; Collis and Hussey, 2014). The aforementioned philosophical assumptions influence the different types of research paradigms. Table 3.1 summarises the philosophical assumptions underpinning different research paradigms. In this research, three main research paradigms: positivism, interpretivism, and pragmatism, will be considered in the next section.

3.4.1 Positivism

Positivism relies on the assumption that reality is singular, objective and independent from researchers (Porta and Keating, 2013; Saunders *et al*., 2016). Researchers do not engage in the social reality being studied but remain external to it. In positivism, the belief is that knowledge can be obtained from systematic methods involving observation and experimentation (Neuman, 2014). This has been the predominant paradigm used by scientists, and a deductive approach has been applied by them (Uddin and Hamiduzzaman, 2009; Bhattacherjee, 2012). Researchers may use existing theory to develop hypotheses. These hypotheses can be tested and confirmed and finally lead to the development of theory and may be further tested by additional research (Saunders *et al*., 2016). Furthermore, positivists believe that the process of research is value-free and that researchers should be detached from what they are researching (O'Gorman and MacIntosh, 2015; Saunders *et al*., 2016). Positivists typically adopt a highly structured research design in order to assist the replication of the research (Gill and Johnson, 2010).

3.4.2 Interpretivism

Interpretivism was considered as a paradigm in the social sciences and was developed as an alternative to positivism in the 19th and 20th centuries (O'Gorman and MacIntosh, 2015). Collis and Hussey (2014) suggested that it was developed as a result of social scientists perceiving that positivism did not address the kinds of research questions posed by them. The belief within interpretivism is that reality is socially constructed (Easterby-Smith *et al*., 2012; Saunders *et al*., 2016). In interpretivism, knowledge is generated from the different perceptions of individuals; subjectively is valued and objectivity is considered to be unattainable. The purpose of interpretivist research is to obtain richer understandings and interpretations of the social world and contexts (Antwi and Hamza, 2015; Saunders *et al*., 2016). Therefore, researchers can interact with the participants to understand the social phenomena from their viewpoints. Furthermore, interpretivists believe that researchers have values and that these values can obscure facts and interpretations that are extracted from the research setting (Collis and Hussey, 2014).

Positivism and interpretivism show the two extremes of a continuum which is based on philosophical assumptions about reality and the nature of knowledge (Collis and Hussey, 2014). However, Onwuegbuzie and Leech (2005) argued that there is a third research paradigm, which is pragmatism, and that this prevails in the social sciences.

3.4.3 Pragmatism

Saunders *et al.* (2016) identified the key principles of pragmatism. They mentioned that pragmatism attempts to reconcile both objectivity and subjectivity, facts and values, precise and 'fixed' knowledge and different contextualised experiences. Researchers focus on problems and seek to contribute practical solutions that inform future practice. Yin (2011) further described pragmatism as having a worldview that supports the selection of appropriate research methods to address the research questions being studied. Researchers may use quantitative, or qualitative methods or engage in mixed methods research, depending upon the research aim and questions (Yin, 2011; Creswell, 2012). Similarly, Kelemen and Rumens (2008) suggest that pragmatists do not always use multiple methods of data collection, but rather they use the method or methods that enable credible, reliable and relevant data to be collected to advance the research.

Table 3.1 Philosophical assumption in different research paradigms

Philosophical assumption	**Positivism**	**Interpretivist**	**Pragmatism**
Ontological (the nature of reality)	Reality is singular, objective and external to the researcher.	Reality is multiple, subjective and interpreted by the researcher.	Reality is the practical consequences of ideas.
Epistemological (the nature of knowledge)	Knowledge comes from the phenomenon that is observable and measurable. The researcher is independent of the phenomena under study.	Knowledge comes from participants' perceptions. The researcher interacts with the phenomena under study.	Focus on problems, practices and relevance Problem solving and informs future practice as its contribution
Axiological (the role of values)	value-free and unbiased research	value-laden research	value-driven research

Source: adapted from Saunders *et al.* (2016) and O'Gorman and MacIntosh (2015)

The selection of the research paradigm is linked to the ontological, epistemological and axiological assumptions of the researcher, as identified in section 3.3. With regard to this study, the researcher adopted pragmatism as a research paradigm as this research focuses on solving the problems in the dispensing process that contributed to dispensing errors. The pragmatist researcher is able to select the most appropriate research methodology to address the researcher questions and research problem that are being investigated (Teddlie, and Tashakkori, 2009). In this study, the researcher used action research

methodology to address the research questions and applied a range of different methods to collect data in each phase of action research. The researcher can also take action to address the problems in the dispensing process. Also, the researcher focused on problem solving and practical outcomes rather than abstract distinctions (Saunders *et al*., 2016).

3.5 Research approach

The two main approaches to reasoning that researchers adopt are deductive and inductive. A deductive approach aims to test the theory developed from academic literature or other sources, whilst an inductive approach seeks to generate or build theory based on the collected data (Burns and Burns, 2008; Cameron and Price, 2009). Deduction is normally focused on explaining causal relationships between concepts and variables, whilst induction aims to explore new phenomena, identify themes and explain patterns (Bhattacherjee, 2012; Creswell, 2014). The use of an inductive approach is suitable for small samples of participants, when compared with the deductive approach, as the researcher can use a variety of methods to collect qualitative data (Saunders *et al*., 2016). For this study, the researcher adopted an inductive approach by using the collected data (e.g. interview, focus group) which were further analysed to identify the different themes emerging from the action research. These identified themes were used to answer the research questions 1,2 and 3.

3.6 Research methodology

The research paradigm is connected to the research design which refers to the choice of research methodologies and methods to be used to address the research questions (Collis and Hussey, 2014). It is important to ensure that the methodological choice is linked to the philosophical assumptions of a research paradigm. The next section provides an overview of four different research methodologies, followed by the justification of the choice made by the researcher. Subsequently, the advantages and disadvantages of the different methodologies are further summarised in Table 3.2.

3.6.1 Case study

Robert Yin, a seminal author in case study methodology, defined the key features of case study as follows: (1) it is an empirical inquiry that investigates a current phenomenon in depth and within its real-life context in which boundaries between the phenomenon and context are not clear or distinguishable; (2) the findings rely on multiple sources of evidence (Yin, 2009). Yin (2009) further stated that the research design for single and

multiple-case studies should be clearly planned by researchers, and these research designs covered five components: 1) the main research questions - the case study is most likely to answer 'how' and 'why' question; 2) study propositions; 3) the units of analysis - individuals, small groups, organizations, communities, etc.; 4) the logic linking data to propositions; and 5) the criteria for interpreting the data.

Collis and Hussey (2014) claimed that although a case study has many advantages, such research is time - consuming and it is sometimes difficult to gain access to a suitable case. Yin (2009) identified the limitations of case study when compared with experiment or survey. He suggested that the findings from a case study are theoretically generalizable rather than being capable of generalization to populations since selection is purposive and context specific rather than random.

With regard to this study, case study was not suitable for this research because the objective of case study is primarily to understand phenomena; it is not the design of choice when attempting to implement an intervention.

3.6.2 Survey

Survey is traditionally associated with a quantitative positivist approach; however, as a design it has also been used to collect qualitative data (Neuman, 2014). For example, researchers can collect the data by surveying the respondents and then these data are analysed thematically, instead of numerically. Survey can be used to collect both primary and secondary data from a sample, which is often randomly selected, with statistical analysis and generalization of results to the population (Collis and Hussey, 2014). It is a structured way of asking the different respondents the same questions (O'Gorman and MacIntosh, 2015) in order to understand the situation being studied without intervening. In line with an experiment, researchers can study a sample and generalize to a population, though the basic principle of experimentation is different in that it aims to test the impact of an intervention on an outcome and control the factors that may affect that outcome (Creswell, 2014; O'Gorman and MacIntosh, 2015).

In addition, as mentioned by Dickinson *et al.* (2007), patient outcomes were infrequently measured, and this identified a key gap in the evaluation phase of action research. Surveying patient satisfaction is the most common way to obtain patients' views on their hospital stay (Labarere *et al*., 2001). Therefore, a survey was conducted to measure the satisfaction of patients who had been hospitalised in the inpatient wards. The

questionnaire was used as a survey instrument to measure the patients' satisfaction with the quality of inpatient pharmacy services before and after the implementation of LSS.

3.6.3 Experimental design

Experimental design is a methodology used to investigate the relationship between two variables known as the independent and dependent variables (Neuman, 2014). The experiment is systematically conducted in a laboratory or a natural setting (Collis and Hussey, 2014). Compared to other research methodologies such as survey, case study and action research, the key feature of an experiment is the researcher's ability to have control over the events that are being studied. An experimental design was not appropriate in this research because the aim was not attempt to test an hypothesis.

3.6.4 Action research

The term 'action research' was coined by Kurt Lewin in 1946, a social psychologist, who was interested in solving social issues (Checkland and Holwell, 1998; Meyer, 2000a; Koshy *et al*., 2010). Action research has been widely used in social settings such as organizational development, education, healthcare and social care (French, 2009). It is designed to bridge the gap between theory, research, and practice (Holter and Schwartz-Barcott, 1993). The key characteristics of action research include; the focus on solving practical problems, the interaction between the researcher and those practitioners who experience the workplace from the inside, the creation of change in the organization and the production of theoretical and practical knowledge (Meyer, 2000a; Waterman *et al*., 2001; Coughlan and Coghlan, 2002; Reason and Bradbury, 2008; French, 2009; Koshy *et al.*, 2010; Soh *et al*., 2011; McDermott and Venditti, 2015). This study used action research as a research methodology and this is explained in the next chapter.

In addition, action research methodology fitted with pragmatism because the researcher applied several qualitative methods to collect the data in each phase of the action research in order to identify the problems in the dispensing process and then to implement potential solutions to address such problems.

- ***Justification of methodological choice***

The main difference between action research and other methodologies is in the role of the researcher. In other methodologies, the researcher is an independent observer whereas in action research, the researcher is involved within a specific context that is being studied

and the aim is to take action to solve problems (Benbasat *et al*., 1987 cited in Farooq and O'Brien, 2015). An alternative approach is that of ethnography which aims to understand social practice, human interactions, behaviours and natural settings (O'Gorman and MacIntosh, 2015). Ethnographers normally collect data by participant observation and interviews with participants to understand the nature of the social phenomenon (Reeves *et al*., 2008; O'Gorman and MacIntosh, 2015). Whilst both ethnography and action research use participant observation to engage in the research setting, ethnographers do not attempt to create action to solve practical problems. Thus, this is a major difference between ethnography when compared with action research.

In contrast to a case study, action research provides a facility for potential interventions in order to solve problems, whilst a case study method provides a means for observing events, collecting and analyzing data and reporting on results (Farooq and O'Brien, 2015). The implementation of an intervention is the distinction between action research, case study, and ethnography.

Moreover, in the healthcare context, a number of the studies have implemented information technology to avoid medication errors. Various studies have implemented CPOE (Jani *et al*., 2008; Kaplan *et al*., 2006) to reduce prescription errors in outpatients and inpatients and have implemented electronic prescriptions to reduce illegible and inaccurate verbal orders (Devine *et al*., 2010). Automated dispensing machines and barcoding have been implemented to minimise dispensing and administration errors (Chapuis *et al*., 2010). Providing education to healthcare providers and patients, implementing medication reviews and reconciliation are important approaches to reduce medication errors in a primary care (Velo and Minuz, 2009; Weber, 2017; WHO, 2017a). Despite all of these approaches, no previous studies have been identified which have used an action research methodology in healthcare to reduce medication errors.

Furthermore, the interaction between the researcher and participants could lead to the solving of dispensing errors in the hospitals and generating lessons learnt because the researcher, the outsider who has expertise in theory, cooperates with the practitioners who have knowledge and experience in their field and understand the setting and practice being studied (Holter and Schwartz-Barcott, 1993; Dickinson *et al*., 2007; French, 2009). The researcher engaged with the participants to identify their views and perspectives on the problems that created the dispensing errors (Farooq and O'Brien, 2015). Therefore,

action research is the most appropriate methodology and other methodologies are not so relevant in this research because:

1) Action research provides the researcher direct access to the area of investigation which is the dispensing process;

2) Action research encourages participants to work directly with the researcher to solve problems in the dispensing process and also to evaluate change;

3) Action research can indirectly improve quality of care, patient safety and increase staff satisfaction because it can bring about change in the inpatient pharmacy;

4) Action research is suitable for healthcare issues (e.g. quality patient care and system improvement) because real events can be solved in real time (Coghlan and Casey, 2001).

Table 3.2 The advantages and disadvantages of different research methodologies

Research Methodologies	Advantages	Disadvantages	Research context
Case Study	Investigates a current phenomenon in depth Uses different methods of data collection Explains the complexities of real-life situations	Time-consuming Sometimes difficult to access a suitable case	Case study is not suitable in this research because is not applicable for implementing an intervention. Also, this research does not aim to understand the complex phenomena.
Survey	Is able to generalize the sample to a population Convenient to gather the data Many variables can be measured without increasing the time or cost.	Individuals may refuse to respond or cannot be contacted. The characteristics of the respondents who answer the questions may lead to errors.	This study used questionnaire as a survey instrument to measure the patients' satisfaction with the quality of inpatient pharmacy services before and after the implementation of LSS.
Experimental Design	Researcher can control the events being studied. Results can be checked and verified.	Experimental failure Human error can affect the results	Experimental design is not appropriate in this research because the aim of this research was not to test an hypothesis.

Action Research	Solves the practical problems Researcher can engage in the phenomena being studied. Appropriate for social and health contexts Able to create change in practice Produces practical and theoretical knowledge	Time-consuming Resistance to change Difficult to achieve and sustain change	Action research is the most appropriate methodology because it encourages participants to work directly with the researcher to solve problems in the dispensing process and also to evaluate change.

The previous section has identified that action research is the most appropriate methodology to be employed in this research. The next sections move on to the action research model, showing the key steps of action research.

- ***Action Research model***

Figure 3.1 shows the action research model which has been developed based on common action research models from existing literature including Lewin (1946), Susman and Evered (1978), Coughlan and Coghlan (2002), O'Leary (2004) and Kemmis *et al.* (2014). According to the models, the cyclical process of AR has been identified as having these main steps: identifying a problem, planning, acting, evaluating and re-planning. The models are used to change practical situations and to solve problems in organizations, education and health and social care. In the healthcare sector, Koshy *et al.* (2010) have identified four phases of the action research process which include identification of an issue and setting up a project, reflection, the planning phase, and the evaluation stage. However, Montgomery *et al.* (2015) conducted a systematic review of action research interventions in healthcare settings, and concluded four specific steps: problem identification, planning of action research, implementation of action research and evaluation of action research.

As action research aims to achieve tacit knowledge, reflection is the key element to obtain such knowledge (Waterman, 1998). Therefore, the model used in this research includes the following key steps: identification of problems, reflection, planning actions, taking actions, evaluation and reflection, and specifying lessons learnt (Figure 3.1).

The model is appropriate for solving practical problems through collaboration between the researcher and practitioners. To identify problems, the researcher gathers the data and feeds back to participants for validation and reduction of the researcher's bias. The

collected data are analysed and finally problems are identified in collaboration with practitioners. The reflection phase ensures the problems are identified correctly; if not the problems need to be identified again. The intervention tool is subsequently planned to solve the problems, and the selected tool is implemented. The next phase is evaluation and reflection which seeks to assess the outcome of actions before moving to the next phase. Participants also reflect on their feelings about the action research project. The main lessons learnt as perceived by participants are identified in the final phase.

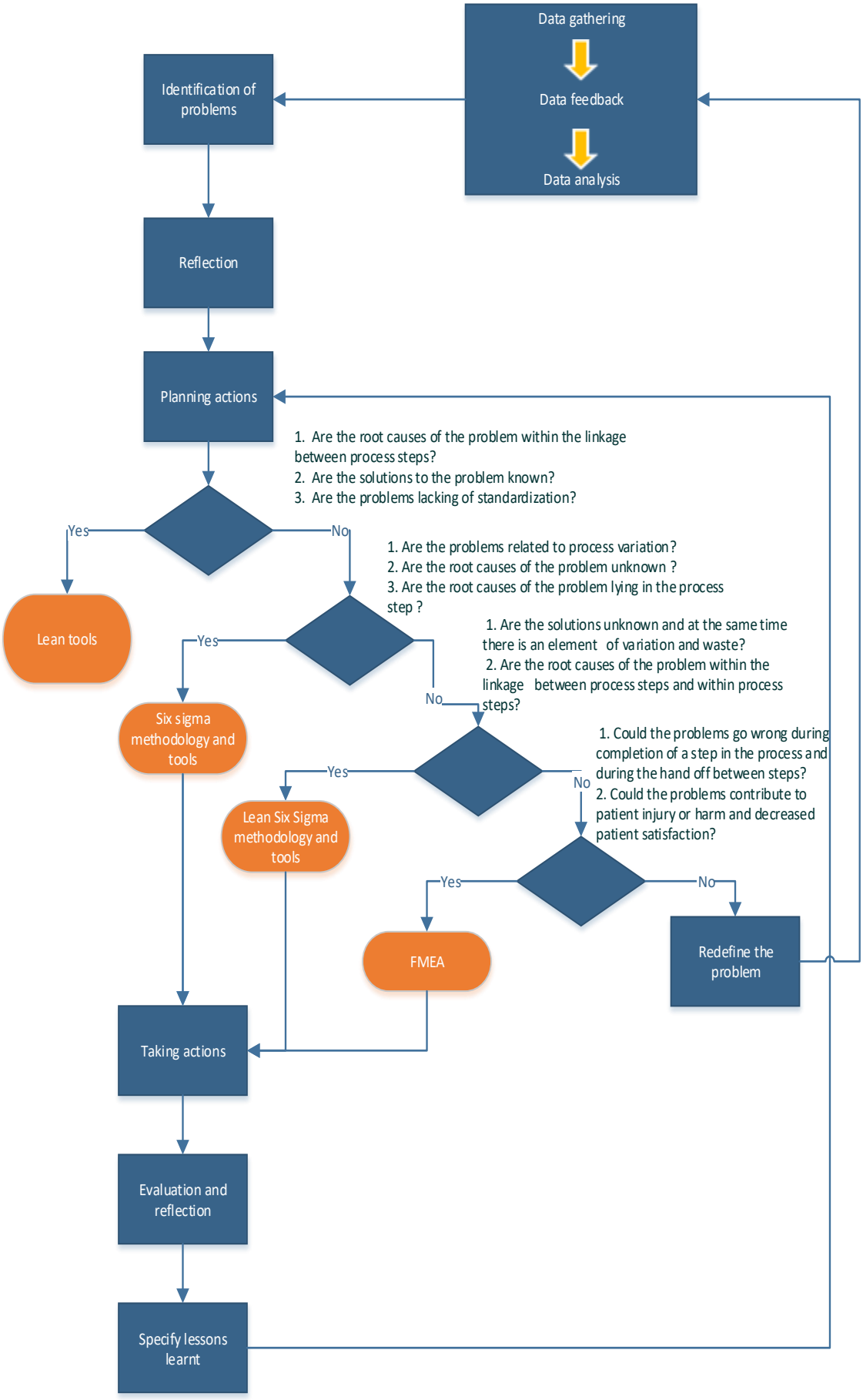

Figure 3.1 Action Research model

In this study, action research was used to explore the implementation of LSS in the inpatient pharmacy in two hospitals. It enabled the following key phases.

1) Identification of problems

In this phase, the researcher collaborated with participants to identify problems relating to dispensing errors. In order to identify such problems, the researcher first collected data by a) conducting a focus group and b) observation of the current dispensing process. Subsequently, the researcher took the gathered data and fed back those data to the participants for validation. Data were further analysed and transcribed by the researcher, with the main problems being identified.

2) Reflection

Participants reflected on the problems identified from the previous phase, in order to make a decision about whether such problems go further to be solved, or whether those problems require redefining.

3) Planning actions

The researcher selected the intervention tools:1) Lean, 2) Six Sigma, 3) Lean Six Sigma or 4) Failure Mode and Effect Analysis (FMEA) with which to solve the identified problems. In this phase, participants were trained by the researcher to understand how to implement the intervention tool.

4) Taking actions

The selected intervention tool was implemented via collaboration between the researcher and participants. The researcher acted as a facilitator to help the participants solve the identified problems.

5) Evaluation and reflection

The researcher collaborated with participants to evaluate the outcome, the challenges and critical success factors of the implementation of the selected intervention tool. The participants reflected on the project and any outcomes for change to the dispensing process.

6) Specifying lessons learnt

The participants and the researcher identified the lessons learnt from the project.

3.7 Research strategies

Research strategies are used to explain the assumptions of data collection and data analysis. As Collis and Hussey (2014) asserted the terms quantitative and qualitative have been used to describe data rather than the research paradigms. The details of quantitative, qualitative and mixed methods research are explained as follows.

3.7.1 Quantitative research

Quantitative research is normally associated with positivism (Ryan, 2006; Bryman and Bell, 2011; Neuman 2014). The key characteristics of quantitative research include: 1) structured data collection techniques; 2) emphasis on measuring variables; 3) testing hypotheses; and 4) verification or proving a relationship (O'Gorman and MacIntosh, 2015; Saunders *et al*., 2016). Quantitative research aims to test objective theories by examining the relationship among variables, and these variables can be measured so that numerical data are further analysed by using statistical and graphical techniques (Ryan, 2006; Creswell, 2014). The data are used to test theory deductively. However, it is also possible to incorporate an inductive approach whereby data are used to develop a theory (Saunders *et al*., 2016). In this research, some quantitative data were captured to evaluate patients' perception of delivered inpatient pharmacy, before and after the implementation of LSS. Prior to the project, the researcher collected the data using face-to-face questionnaires by reading each question to the patients and then completing the questionnaires. After the implementation of LSS, the data were collected by a telephone questionnaire after the patients had been discharged from hospital to home.

3.7.2 Qualitative research

Qualitative research is generally associated with interpretivism (Goldkuhl, 2012; Collis and Hussey, 2014). Qualitative research aims to explore and understand the meaning of phenomena being studied through eliciting participants' views (Creswell, 2014). A number of authors, such as Yin (2011), Creswell (2014) and Neuman (2014) identify key features of qualitative research as follows:

(1) natural setting: researchers tend to collect the data from the field where participants have experienced the problems or issues being studied;
(2) studying participants'meanings: researchers keep focusing on the learning of participants instead of the meaning that researchers bring to the research;
(3) identifying contextual conditions;

(4) contributing insights into an existing or developing conceptual framework or theoretical contribution;
(5) using multiple sources of data: qualitative researchers collect several forms of data such as observations, interviews, and documents.

Qualitative data consist of detailed descriptions of situations, people, interactions, direct quotations from people about their experience, attitudes, beliefs, and thoughts (Patton, 1980). Qualitative data provide depth and detailed information which emerges from direct quotations from people and descriptions (Patton, 1980). In this research, several forms of qualitative data, including focus group, interview and field notes, were obtained to identify the problems in the dispensing process, to evaluate the outcome of LSS implementation, to explore how participants felt about the project, and to specify the lessons learnt.

3.7.3 Mixed methods research

Mixed methods is a combination of quantitative and qualitative research (Bryman and Bell, 2011; Creswell, 2014; Flick, 2014). It combines the use of qualitative and quantitative data collection techniques and data analysis (Saunders *et al*., 2016). Mixed methods have emerged in order to minimize the bias and weaknesses of qualitative and quantitative methods. It can be used deductively, inductively or with an abductive approach to develop the theory (Saunders *et al*., 2016). Creswell (2014) claimed that the combination of both approaches may provide more understanding of research questions rather than by the adoption of an approach alone. However, it is dependent on the nature of the problem and the researcher's assumptions to decide the suitable approach for the research.

3.8 Research methods

A range of methods were used to collect the data in order to ensure that the research design met the philosophical assumptions based on pragmatism (Collis and Hussey, 2014). The details of the data collection methods namely interviews, focus groups, observation, field notes, research diary, and questionnaires, are explained in the next section, followed by the justification of the data collection methods adopted.

3.8.1 Data collection methods

A. Interviews

An interview is a method used to gather data from participants in order to understand their perspectives, feelings, and thinking. Brinkmann (2008) stated that it is a reflective process that allows the participants to describe their experiences regarding the investigated issues. Researchers cannot observe the participants' thoughts, feelings or intentions (Patton, 1980). The interview allows the researcher to understand participants' perspectives on the assumption that their perspective is meaningful, knowable and capable of being made explicit (Patton, 1980).

Interviews can be categorized into three types according to the degree of imposed structure: structured interview; semi-structured interview; and unstructured interviews (Koshy *et al*., 2010; Saunders *et al*., 2016; Collis and Hussey, 2014). In a structured interview, researchers use an identical set of questions which are pre-determined and they only ask these questions of participants. In a semi-structured interview, the researcher can prepare questions and may also have a set of subquestions, sometimes referred to as follow-up questions or probes, which can be used to explore further and gain more information (Antony *et al*., 2019b). With an unstructured interview, there is no list of predetermined questions but often a general topic guide, so it provides an opportunity for open exploration of interviewees' perspectives. Interviews can be conducted using different approaches including face-to-face, group interviews, telephone, and online (Saunders *et al*., 2016). The characteristics, advantages, and disadvantages of these methods are summarised in Table 3.3.

In this study, the researcher used semi-structured interviews to ask participants to evaluate the outcome of the implementation of LSS and reflect on the action research project. Semi-structured interviews were also used to capture the challenges, success factors of LSS implementation and the lessons learnt by participants.

Table 3.3 The different ways to conduct interviews

Methods	Description	Advantages	Disadvantages
Face-to-face or one-to-one interview	Researcher interviews each individual participant in person.	Comprehensive data can be collected. Researchers have the opportunity to develop a rapport, or relationship with the interviewees. Researcher has an opportunity to observe the interviewee.	Time-consuming The interviewer may lead the interviewee in other directions.
Group interview	Researcher interviews a group of participants.	Group interviews may produce data that is not gained through a face-to-face interview process because individuals hear the response of others. The group dynamic may encourage the participants to engage more freely in the process giving information.	Participants may feel constrained or intimidated by the group setting.
Telephone	Researcher conducts the interview by telephone.	Reduces cost of travelling Convenience	A long interview may not be possible as interest can wane over the telephone and the cost of the call may be high.
Online	Researcher conducts the interview through the internet.	Overcomes some of the cost constraints.	Limited only the interviewees who can access to the internet.

B. Focus groups

A focus group is the data collection method which brings together a group of people to discuss a particular topic which has been clearly identified by the researcher (Morgan, 2008; Nyumba *et al*., 2018). Participants may feel empowered to express their opinions and the researcher is able to capture their different perspectives and viewpoints. Participants should feel free to discuss a particular topic, though the moderator takes an important role in controlling the aspects being discussed (Morgan, 2008). The key roles

of the moderator or facilitator include: 1) encouraging participants to focus on the topic being studied; 2) not leading the group to provide specific opinions; and 3) engaging all members of the group in the discussion (Saunders *et al*., 2016).

Several researchers claim there is a choice between using focus groups and individual interviews (Morgan, 2008; Quinlan *et al*., 2019; Neuman, 2014; O'Gorman and MacIntosh, 2015). Morgan (2008) stated that the structure of interviews is based on the researcher's interests, and there is an important role for the researcher to identify how the conversation proceeds. Quinlan *et al.* (2019) said that focus groups are similar to some aspects of group or individual interviews. However, the key differences are that in a focus group, the researcher encourages the participants to focus on the phenomenon under investigation and facilitates interaction across the group, while in individual interviews, the researcher asks each participant direct questions about the phenomenon being investigated. Morgan (2008) also identified the difference between the two methods in that focus groups are useful when the researcher aims to obtain the data from a range of participants at the same time, while individual interviews are more useful when the goal is to obtain rich data from each participant.

With regard to this study, the researcher conducted a focus group to obtain the different participants' viewpoints and perspectives regarding the problems that they had encountered within the dispensing process in order to identify the problems in the dispensing process.

C. Observations

Observation is a key method to collect data by observing people's actions and behaviours, activities and phenomena, and subsequently recording the data in field notes (Collis and Hussey, 2014). Thus observation involves the systematic recording, description, and interpretation of individuals' behaviour (Saunders *et al*., 2016). The researcher can then understand in detail how people work and communicate and how activities are undertaken. There are two main types of observation: participant observation and non-participant observation although it is accepted that there is a continuum between the two which enables a merging of participant and non-participant (Koshy *et al*., 2010; O'Gorman and MacIntosh, 2015). With participant observation, the researcher engages in the phenomenon or activity being studied. On the other hand, with non-participant observation, the researcher is an outsider to the situation under study (O'Gorman and

MacIntosh, 2015; Quinlan *et al*., 2019) and only observes and records the conversation of participants.

Koshy *et al.* (2010) identify that the nature and purpose of observation process and linked it with the level of structure that researchers adopt structured, semi-structured, or unstructured. With structured observation, researchers may design or use an existing observation schedule to record behaviour patterns and the number of actions and interactions. However, McKechnie (2008) identified that in qualitative research, an observational schedule can be prepared as a guideline for data collection. In semi-structured observations, researchers can still use a pre-defined schedule, but there is some flexibility that enables them to record unexpected outcomes. Unstructured observations allow researchers to capture all aspects of phenomena being studied.

In this study, the researcher used an observation method to observe the current dispensing process to understand how medications were being dispensed, how the patients received their medications, as well as how people were working and interacting.

D. Field notes

Several studies encourage researchers to take field notes in order to enhance data and obtain a rich context for analysis (Brodsky, 2008; Creswell and Plano Clark, 2011; Phillippi and Lauderdale, 2018). The researcher can record descriptive details of the physical setting, people, reflections on the data and the daily process of activities (Mulhall, 2003; Brodsky, 2008). Patton (1980, p.164) summarised that fieldnotes consist of

> "descriptions of what is being experienced and observed, quotations from the people observed, the observer's feelings and reactions to what is observed, and field-generated insights and interpretations"

With regard to Patton's (1980) explanation, the researcher can record the detailed descriptions of what is being observed when engaged in the research setting, where the researcher believes that such information is valuable to the research. Importantly, field notes should be recorded as soon as possible when the events are being observed, or shortly after, in order to ensure that the details are not lost (Mulhall, 2003). Field notes can be used to record non-textual information from interviews and focus groups which cannot capture aspects such as facial expression, setting characteristics, impressions and

assumptions (Phillippi and Lauderdale, 2018; Brodsky, 2008). The researcher took notes continuously to record what happened in every phase of the action research.

E. Research diary

A research diary or a personal journal is useful as a means by which the researcher can record their experiences, thoughts, reflections, and feelings throughout the research (Robson, 2011; Koshy *et al*., 2010). It provides an opportunity for the researcher to write about emotions, introspections, and self-reflections (Vannini, 2008). There are two types of research diary: 1) the personal diary kept by the researchers providing their experiences 2) the diary used by the researchers as a data collection tool (Snowden, 2015; Vannini, 2008). In this research, the researcher used a research diary as data to provide experiences, self-reflection, and feelings throughout the action research. The advantages and disadvantages of different data collection methods are summarised in Table 3.4.

Table 3.4 The advantages and disadvantages of different data collection methods.

Data collection methods	Advantages	Disadvantages
Interview	Provides rich information Provides a relaxed context for the exploration of ideas Allows unexpected information which may be useful	Time-consuming Resource intensive May generate irrelevant data Susceptible to interviewer bias
Focus groups	An effective method to gather different viewpoints Diverse viewpoints can be discussed.	Some participants may feel threatened by other group members. Facilitator's bias may lead to influence in the discussion. Complex to analyse the data
Observation	Primary information is collected. Provides an opportunity for the researcher to take note of participants' actual behaviour Capture data in more natural circumstance	Researcher's bias The researcher may misinterpret what they observe. The person being observed may change their behaviour.

Field notes	Supplement information obtained from other methods. Support researchers to construct the research story	It is sometimes difficult for the researcher to sustain writing. Time-intensive
Research diary	Support researchers to construct the research story The personal reflective writing is a part of professional development.	It is sometimes difficult for the researcher to sustain writing.

Source: adapted from O'Gorman and MacIntosh (2015), Koshy *et al.* (2010), and Mulhall (2013)

F. Questionnaires

The questionnaire was used as a survey instrument to measure the patient's satisfaction with the quality of inpatient pharmacy services before and after the implementation of LSS. The questionnaire design is explained as follows.

- Questionnaire design

The questionnaire was derived from reviewing existing inpatient satisfaction questionnaires (Arab *et al*., 2014; Salehi *et al*., 2017; Meesala and Paul, 2018). The questionnaire consisted of two main parts. The aim of the first part was to understand the general information about patient demographics by a list of questions. These included: gender, age, educational level, and hospital stay characteristics. The second part employed rating questions to measure inpatient satisfaction within five dimensions including:

1) medication received;
2) drug information received from the pharmacists;
3) nursing and daily care;
4) nursing and pharmacist satisfaction;
5) overall quality of care and services

A five-point Likert rating scale was adopted for each item, ranked from strongly disagree (1) to strongly agree (5), allowing respondents to indicate the level of agreement with the statements. The final part was an open-ended question which asked the respondents to provide any ideas to improve the inpatient pharmacy service. This questionnaire was piloted with five academics and five healthcare professionals (Antony *et al*., 2007). These

ten people provided constructive feedback on a number of questions in the survey instrument and the researcher made amendments to such questions (Antony *et al*., 2019b). The survey was carried out with a purposive sampling of 30 inpatients. The inpatients were chosen based on the following selection criteria: 1) they had stayed in the inpatient wards for more than 24 hours and were then discharged to their homes and 2) they were able to answer the questionnaire.

3.8.2 Justification of data collection methods

Different data collection methods were used in each phase of the action research which included: observation, a focus group, semi-structured interviews, and field notes. In order to identify the problems relating to dispensing errors which occurred in the dispensing process, the researcher used an observation method to observe the current process of medication dispensing to understand how medications were being dispensed, how the patients received their medications, as well as how people were working and interacting. The researcher also conducted a focus group to obtain the different participants' viewpoints and perspectives regarding the problems that they had encountered within the dispensing process. Compared with individual interviews, the focus group could bring all participants together to discuss and express their ideas related to the problems in the dispensing process.

The researcher used semi-structured interviews to ask participants to evaluate the outcome of the implementation of LSS and reflected on the action research project. Semi-structured interviews were also used to capture the challenges, success factors of LSS implementation and participants' lessons learnt. The purpose of using interviews is to capture their experiences and perspectives which distinguishes them from other methods (Patton, 1980). With structured interviews, the researcher can use follow-up questions to clarify further and obtain more information from the participants. The researcher kept taking notes to record what happened in every phase of the action research. Although taking notes is time-intensive, it is important for the researcher to keep writing notes as close to the action as possible in order to obtain the rich details of the data. Field notes are an important component to capture the data that cannot be obtained from the interviews and focus group. Table 3.5 summarises the data collection methods used in each phase of action research in the two hospitals.

Table 3.5 Data collection methods in each phase of the action research methodology.

Action research methodology	Data collection methods	Outcome	Justification
1.Identification of problems	1. Focus group The researcher conducted a focus group to capture the participants' perspectives in order to identify where the problems lay in the dispensing process. 2. Observation The researcher observed the current dispensing process to understand where the process starts and ends, and then made field notes. 3. Field notes	Problems identified and understood by the researcher.	Compared with individual interviews, the focus group can bring all participants together to discuss and express their ideas related to the problems in the dispensing process. The researcher kept taking notes to record what happened in every phase of the action research. Field notes are an important component to capture the data that cannot be obtained from the interviews and focus group.
2. Reflection	1. Field notes	The decision as to whether the problems were expanded for solving or whether to redefine the problem.	
3. Action planning	1. Field notes	Training and intervention tool were developed, aimed at facilitating change in the dispensing process.	
4. Taking action	1. Observation The researcher observed the situation and made field notes to gather all of the data related to the implementation of the intervention tool. 2. Field notes	The selected intervention tool (LSS) was implemented through collaboration between the researcher and participants.	
5. Evaluation and reflection	1. Semi-structured interviews Participants were asked to express their feeling about the project, evaluate the outcome of LSS implementation. In this phase, participants were also asked to indicate success factors and challenges in the use of LSS to reduce medication errors. 2. Field notes 3. Questionnaire	The impact of the intervention tool for solving the problems was assessed by participants. The challenges and success factors of LSS implementation. The satisfaction of inpatients was compared before and after the LSS implementation.	The researcher used semi-structured interviews to ask participants to evaluate the outcome of the implementation of LSS and reflect on the action research project. With structured interviews, the researcher can use follow-up questions to clarify further and obtain more

			information from the participants.
6. Specifying lessons learnt	1. Semi-structured interviews Participants were asked to express the lessons learnt from the project. 2. Field notes	The lessons learnt were identified.	

In addition, more detail of how the data were collected in each phase of the action research methodology is given in the next chapter.

3.9 Data analysis

The choice of method for analysing the research data depends on the nature of the research questions, research paradigms and research strategy (Collis and Hussey, 2014; Saunders *et al*., 2016). Qualitative data were collected through different phases of the action research. Thematic analysis was adopted as the most appropriate approach to analyse the qualitative data gained in this study. Thematic analysis provides a systematic way to analyse qualitative data (Braun and Clarke, 2006) which leads to rich descriptions, explanations and theorising (Saunders *et al*., 2016). The primary reason for using this approach is that it allows the researcher to identify themes to understand the problems in the dispensing process and the views of participants after the implementation of LSS through the action research, the challenges and success factors of LSS implementation, and the lessons learnt from the project. The study adopted a procedure used in thematic analysis proposed by Creswell (2014), Collis and Hussey (2014) and Saunders *et al.* (2016). The key steps of data analysis were as follows.

1) Preparing the data for analysis

Preparing data analysis involves transcribing interviews, typing up notes, and arranging different types of data (Creswell, 2014). The interviews and focus group were audio-recorded and subsequently transcribed verbatim (Dickinson *et al*., 2007). Field notes and a researcher diary were typed using the personal computer, at the end of each day after data collection. Then, the transcriptions were sent back to the participants for review and approval (Psychogios *et al*., 2012).

2) Familiarisation with the data

In order to analyse qualitative data, producing transcripts and data familiarisation are important elements (Saunders *et al*., 2016). The researcher is not able to understand the

data without this familiarity (Saunders *et al*., 2016). Although, this phase may be time-consuming, it is important for the researcher to read transcriptions several times (O' Gorman and MacIntosh, 2015). The researcher listened and re-listened to the audio recordings of the interviews and the focus group, read the transcripts and notes taken in order to become familiar with them and then they were summarised. After this process, all collected data were further reduced by the use of coding.

3) Coding

Coding is the process of organising the data into the segments that have similar meanings (Rossman and Rallis, 2016; Saunders *et al*., 2016) with the aim of conceptualising and reducing the data (Corbin and Strauss, 2008). After familiarisation with the data, the researcher used a manual approach to code the data in line with the questions. The researcher labelled a unit of data with the appropriate code(s) in the margin of the transcription. In this research, codes were developed based on the literature related to the challenges and critical success factors of LSS implementation in the healthcare sector. Some of the codes were generated by the researcher and others were based on terms used by participants (Creswell, 2014; Saunders *et al*., 2016). After coding the data, the researcher checked the accuracy of all codes against the unit of data.

4) Identifying and refining themes

Searching for themes begins when all the data set has been coded (Saunders *et al*., 2016). The codes were grouped into categories and subsequently main themes were generated (Collis and Hussey, 2014; O'Gorman and MacIntosh, 2015; Nilvarangkul *et al*., 2016). After the themes were created, the researcher checked these themes against the extracted codes to ensure that they were related to each other (O'Gorman and MacIntosh, 2015). In this stage, the researcher is able to reorganise the extracted codes under the relevant themes or sub-themes (Saunders *et al*., 2016).

In addition, this action research study involved some quantitative data from the measurement of patients' satisfaction with the quality of inpatient pharmacy services before and after the implementation of LSS. A dependent t-test was conducted to compare patients' satisfaction before and after the LSS implementation. In this instance, quantitative analysis software, SPSS, was used to analyse the data (Rowley, 2014).

3.10 Ethical considerations

This study has received ethics approval from Heriot-Watt University, Hospital A and Hospital B. For Hospital B (a teaching hospital), the researcher applied for ethical permission by submitting documents including the research proposal, curriculum vitae of the researcher, supervisor, and participants, informed consent form, questionnaires, and list of questions for interview and focus group as required by the Office of Human Research Ethics Committee (HREC), Faculty of Medicine. The researcher and participants completed research training workshops in Good Clinical Practices (Figure 3.2). It took four months to receive ethics approval from Hospital B. However, for Hospital A, the only documents required by the Hospital were the research proposal, questionnaires and a list of questions for interviews and focus group.

The researcher used a participant information sheet and informed consent document to provide a verbal explanation of the study for the participants and to gain their consent to participate. The researcher reviewed the consent document line by line to ensure that the participants understood the study. Subsequently, the participants signed and dated the informed consent document before taking part in the study. The participant was free to withdraw consent and/or decline to participate in the study at any time before or after signing the consent document. The participant could provide the researcher with the reason(s) for leaving the study, but is not required to do so. The participants may have felt a little stressed if or when required to discuss the questions relating to the problems of dispensing errors in the hospital. However, in order to prevent this potential source of harm, the researcher removed participants' names throughout the study, thereby ensuring participant anonymity. At the end of the focus group and interview, the researcher returned the transcript of each individual, thereby offering that person the option to remove any passages they would not wish to be included. The researcher sent an anonymized set of integrated notes for the whole group but not identifying what each individual said.

The researcher securely stored paper data and electronic data in password protected environments. The researcher will ensure that in the future no information gained from participants is disclosed in ways that may identify an individual. All the data and information gathered from this study are being treated with care and will not be shared with anyone outside the hospital.

As aspect of this research involved vulnerable participants (elderly people). Before administering the questionnaires to patients who were elderly, the Heads of the different wards in both hospitals explained to patients and their relatives that the researcher would be conducting the questionnaire survey. To reduce patients' potential anxiety or distress, the researcher explained to them that this survey was not part of, or connected with their treatment. If the patients did not wish to participate in this study, it would not affect their treatment (Richards and Schwartz, 2002).

Regarding the information about medication errors from both hospitals, the researcher asked for permission from both hospitals to use the data about errors. Both hospitals were willing to provide the information about them. It was clear that knowledge of the errors would not affect the staff who made the errors. The study does not reveal the names of these two participating hospitals in order to maintain confidentiality and to protect the hospitals' reputation.

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Figure 3.2 Researcher's certification of good clinical practices

3.11 Chapter summary

Figure 3.3 shows the research design of this study. This chapter has identified the philosophical framework which guided the conduct of the research. The researcher adopted a paradigm of pragmatism which was linked to the choice of methodology and methods for addressing research questions. As a pragmatist, the belief was that the

research question can be addressed by selecting appropriate methods. The researcher adopted an inductive approach to identify different themes emerging from the action research. Furthermore, the researcher used an action research methodology to address research questions and meet the philosophical assumptions of pragmatism. Figure 3.3 shows how different research methods were used and how they were linked to the philosophical research paradigm. The next chapter presents the key characteristics of the action research methodology and how data were collected in each phase of action research.

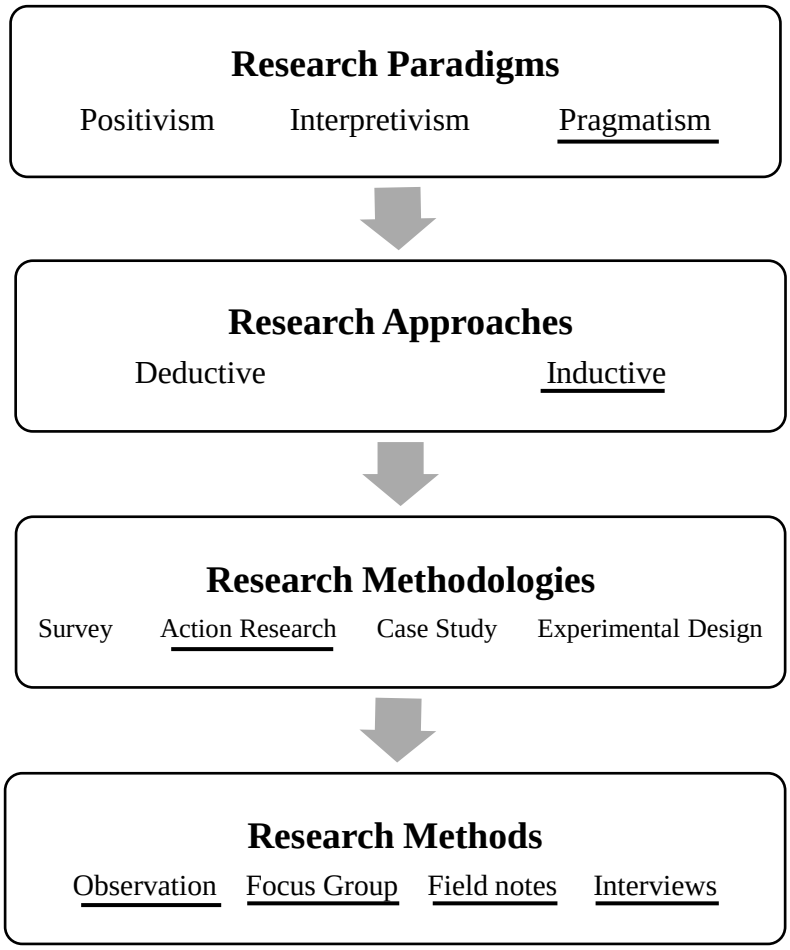


Figure 3.3 Research design

CHAPTER4 – ACTION RESEARCH METHODOLOGY

4.1 Introduction

This chapter illustrates how an action research methodology was employed in the inpatient pharmacy in Hospital A and Hospital B. The first section explains the application of action research in the healthcare sector, followed by the key characteristics of action research. The next section describes the research setting showing the medication distribution system that was implemented in Hospital A and Hospital B. Then, the key phases of the action research methodology and how the data were collected in each phase are further described. Lastly, the final section explains how the research has been carried out rigorously.

4.2 Action research in healthcare

The term 'action research' was coined in 1946 by Kurt Lewin, a social psychologist, who was interested in solving social issues (Checkland and Holwell, 1998; Meyer, 2000a; Waterman *et al*., 2001; Koshy *et al*., 2010). Subsequently, it has increasingly gained prominence in healthcare settings (Meyer, 2000b; Trondsen and Sandaunet, 2009). Parmelli *et al.* (2011) pointed out that healthcare organizations aim to implement interventions in order to change the organizational culture and to improve healthcare performance. Several researchers have indicated that the main purpose of action research is to create change in an existing situation (see, for example, Meyer, 2000b; Tanna, 2005; Koshy *et al*., 2010). Action research exhibits the key characteristics that can facilitate change in healthcare settings and support healthcare delivery development (Tanna, 2005). Action research places emphasis on collaboration, participation, and empowerment of healthcare staff to engage with the researcher to generate solutions to practical problems, and to improve patient safety and clinical practice (Coughlan and Coghlan, 2002; Soh *et al*., 2011; Farooq and O'Brien, 2015).

A number of studies have shown that action research is an approach that can improve the quality of care, staff satisfaction and bring about change in the healthcare setting (Waterman *et al.*, 2005b; Portillo, 2008; Montgomery *et al*., 2015). Moreover, action research is able to promote a bottom-up approach in which the researcher collaborates with healthcare staff to develop and implement solutions in relation to important issues in healthcare settings (Parkin, 2009; Montgomery, *et al*., 2015;). However, Waterman

(2001) asserted that a high rate of turnover participants in action research study could cause problems. In this study, at the beginning of the project, the researcher described each phase of the action research methodology to participants and explained their roles. The next section delineates the key characteristics of action research.

4.3 The key characteristics of action research

Four key characteristics of action research have been identified by Holter and Schwartz-Barcott (1993) including: collaboration between the researcher and the practitioners; the definition of the problem; the development of theory; and change in practices. These key characteristics have been widely cited by several authors such as Dickinson *et al.* (2007), Portillo (2008) and Casey (2007). The researcher adopted the key characteristics of action research presented by Holter and Schwartz-Barcott (1993) and applied them to this study including: solving problems in the dispensing process; collaboration between the researcher and practitioners who have experience of the workplace; bringing about change in the inpatient pharmacy service; and generating theoretical and practical knowledge and extension of the existing theory (Figure 4.1). The details of each key characteristic are explained in the next section.

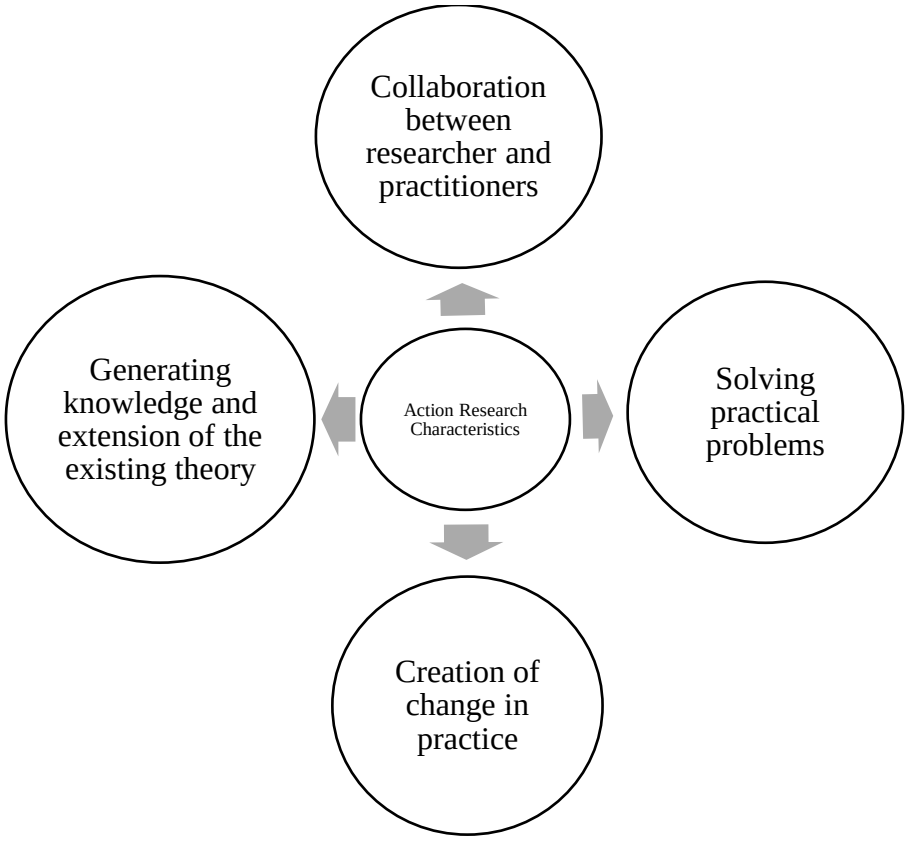


Figure 4.1 Key characteristics of action research

4.3.1 Solving practical problems

Action research is an effective methodology that can be applied to solve practical problems in the organizations through collaboration between the researcher and participants. Action research focuses on solving problems within a situation and this characteristic differentiates action research from other approaches (Parkin, 2009; Nørgaard and Sørensen, 2016). For example, Matos *et al.* (2016) implemented LSS through an action research approach to solve problems such as excessive flows and inventory mismanagement in the operating unit.

It can also be used where practitioners decide to research their own practice, or external researchers can engage with them to identify problems and implement interventions (Dickens and Watkins, 1999; Meyer, 2000a). However, Winter and Munn-Giddings (2001) claimed that one of the problems with action research is how to engage participants in the identification of problems in their practices. In relation to this study, the participants perceived the need to change their dispensing process and, therefore, they were willing to identify the problems that they had been experiencing. The participants considered that the dispensing errors could cause patient injury, patient dissatisfaction, and even death. Although, they had implemented several solutions such as using 'tall man letter' to differentiate 'look alike sound alike' medications these errors remained and could not be resolved by participants.

Additionally, the outcomes from action research methodology are not only the generation of solutions to solve problems, but also they contribute to the development of practical and theoretical knowledge (Coughlan and Coghlan, 2002). Similarly, Meyer (2000b) stated that action research focusses on undertaking research in action and generating knowledge about that action, unlike other research methodologies which aim purely to generate knowledge and understanding of the problems.

4.3.2 Collaboration

The collaboration involves the interaction between researchers and practitioners (Holter and Schwartz-Barcott, 1993; Tanna, 2005; French, 2009) which could lead to the solving of problems in a particular situation. Holter and Schwartz-Barcott (1993) described practitioners as those members of the organization who know the workplace from the inside. The researcher is the outsider who has expertise in theory and cooperates with the practitioners who have the knowledge and experience in their field, and who understand

the workplace being studied (Coughlan and Coghlan, 2002; Dickinson *et al*., 2007). For example, nurses, including a head nurse collaborated with academic researchers to develop a new nursing handover programme in a paediatric ward (Waterman *et al*., 2005a). However, Soh *et al.* (2011) pointed out that getting staff involved in the action research is a difficult issue commonly faced by an action research team. This might be due to a lack of motivation because healthcare staff normally encounter an excessive workload daily. However, in this study, the participants were aware of patient safety and were encouraged by the researcher so that they were willing to collaborate with the researcher.

In order to bridge the gap between research and practice, action research has an ability to get the researcher and practitioners working together (Whitelaw, 2003; Voigt *et al*., 2014). Dickens and Watkins (1999) claimed that, without collaboration, researchers develop theory without applying it whilst practitioners may engage in action that is uninformed. In relation to this study, the researcher brought expertise in LSS and was present in the inpatient pharmacy in both hospitals for 10 months.

The nature of continuous collaboration between the researcher and participants ranges from periodical participation to facilitating the implementation of the intervention (Holter and Schwartz-Barcott, 1993). This study applied a mutual collaborative approach, as identified by Holter and Schwartz-Barcott (1993), in which the researcher and participants collaborated to identify problems, generate solutions and evaluate outcomes. The researcher continuously collaborated throughout the study with healthcare practitioners including pharmacists and pharmacy technicians who have been working in the inpatient pharmacy for many years and therefore had considerable experience. The power of the participants was equal during all phases of the action research process (Meyer, 2000b; Sarvestani *et al*., 2017).

4.3.3 Creating change

The purpose of undertaking action research is to bring about change within an organizational setting (Parkin, 2009). Parkin (2009) stated that the primary purpose of action-based research is to bring about change in a specific situation which aims to solve real-world problems. Action research has an ultimate aim to make change in an organizational setting (Meyer, 2000b; Trondsen and Sandaunet, 2009; Soh *et al*., 2011) by an insider or an outsider of the organization. For example, a study by Dickinson *et al.* (2007) employed action research to improve mealtimes for elderly people in a hospital.

The results showed that through action research several changes to in nursing practice and the mealtime environments was possible, which led to improvements in the patients' experience.

However, several authors have argued that the implementation of change in healthcare is difficult and challenging (Saka, 2003; Diefenbach, 2007). Indeed, this was a factor in this research and it was difficult to instigate a change in the dispensing process or pharmacy service environment. However, the empowerment created by the engagement of practitioners in collaboration with the researcher was helpful to make change happen successfully. In order to engage participants in the change process in the inpatient pharmacy, the researcher first contacted the Head of Pharmacy Department from both hospitals. Then, the researcher explained to them the details of the action research project with the implementation of LSS to reduce dispensing errors to them. Afterwards, the researcher met the participants and explained the action research project to them. As pointed out previously, the participants finally understood the need to change and participated in the action research project.

Furthermore, Holter and Schwartz-Barcott (1993) indicated that the occurrence of change in practice depends on the nature of the identified problems. Change in processes relies on the intervention that is identified by the researcher before entering the field or through collaboration with the practitioners. In this study, the researcher both collaborated with practitioners and identified that there was a problem, and thus changed the current practice of the inpatient pharmacy by reducing errors in the dispensing process. LSS and its tools and techniques were developed and implemented in the field with the aim of facilitating change in the dispensing process.

4.3.4 Generating theoretical and practical knowledge

The final outcome of action research is to produce both theoretical and practical knowledge which is useful for healthcare practitioners (Reason and Bradbury, 2008). Similarly, Huang (2010) identified that action research aims to create knowledge arising from a collaboration between the researcher and practitioners in a specific context. For example, Portillo (2008) found that practical knowledge, for example, social rehabilitation programmes for the improvement of nursing role in social care, and theoretical knowledge, such as relating to nursing's roles in clinical rehabilitation, could be developed through action research. With respect to the current study, the practical

knowledge generated was that LSS can be used to reduce medication errors in the hospital. The theoretical knowledge was the knowledge about LSS methodology.

Using action research, theory can be generated, refined or expanded from the results achieved through the research process (Holter and Schwartz-Barcott, 1993; Coghlan and Casey, 2001; Reason and Bradbury, 2008; French, 2009). The researcher can develop a new theory or enhance existing theories (Holter and Schwartz-Barcott, 1993). In relation to this study, the researcher has achieved an extension of organization learning theory in the context of medication errors by considering how single-loop or double-loop can be created in the hospital. However, Auriacombe (2015) claimed that the involvement and improvement of problems in real life is the most important contribution of action research. The researcher concurred with Auriacombe (2015), in that solving the problem of dispensing errors is considered to be another contribution of action research.

4.4 Research Setting

The study was conducted in the inpatient pharmacy at two hospitals. These case hospitals were selected, based on convenience, as the researcher knew who to contact in these hospitals. These cases also provided rich information and encountered with medication error issues. The researcher decided to use two case hospitals because it allowed the researcher to analyse the data across cases in order to draw out similarities and differences between Hospitals A and B (O'Gorman and MacIntosh, 2015). Hospital A is a tertiary care hospital and Hospital B is a large super tertiary care hospital. The following sections explain the details of the inpatient pharmacy and medication distributions of Hospital A, followed by Hospital B.

4.4.1 Hospital A

Hospital A is a public hospital operated under the Ministry of Public Health, and it can accommodate up to 508 beds. It has been used for placement in clinical practice for medical and nursing students. The hospital provides inpatient, outpatient, and accident and emergency services.

- ***Inpatient pharmacy service***

The staff in the inpatient pharmacy include 11 pharmacists and 14 pharmacy technicians. The inpatient pharmacy implements the daily dose system to distribute medication to 12 wards and implements the three days dose system to distribute medication to 8 wards in

Hospital A. The details of the medication distribution system are explained in the next section.

- ***Medication distribution system***

The medication distribution is a key responsibility of the pharmacy service (American Society of Hospital Pharmacists, 1993). In the hospital pharmacy service, there are four types of system which are used to distribute medications including: 1) bulk ward stock replenishment; 2) individual medication order system; 3)unit dose system; and 4) automated medication dispensing (Management Science for Health, 2012).

In Thailand, a unit dose distribution system is the standard drug distribution system endorsed by the Hospital Accreditation (HA). The unit dose distribution system means that medications are dispensed in ready to administer form, where each dose of medication is packed separately and need to be supplied to inpatients within 24 hours (American Society of Health-System Pharmacists, 1993). However, due to the limited number of pharmacists, pharmacy technicians and financial resources, the inpatient pharmacy adapted the unit dose distribution system into a daily dose distribution system; therefore, the time used to prepare medications could be reduced (Leelasiriwilas *et al*., 2005). Thus, the daily dose distribution system becomes the most common system for the distribution of medication in Thailand (Chaiyakunapruk *et al*., 2016).

The daily dose is a system of medication distribution in which a portable medication cart contains a drawer for each patient's medications, as prepared by the pharmacy technicians. The daily dose distribution system involves dispensing of medications to patients in the wards on a daily basis and for 24-hours' duration. The medication carts are filled by using manual methods. On the other hand, three days dose system is a system whereby medications are distributed with three days' supply for inpatients. This study focuses on reducing medication error in the daily dose distribution system and attempts to reduce the relatives of patients waiting time in three days dose distribution system. The details of Lean methodology to reduce the relatives of patients waiting time are explained in the next chapter (section 5.2.2). The next section explains the process of the daily dose distribution system, as illustrated by Figure 4.2.

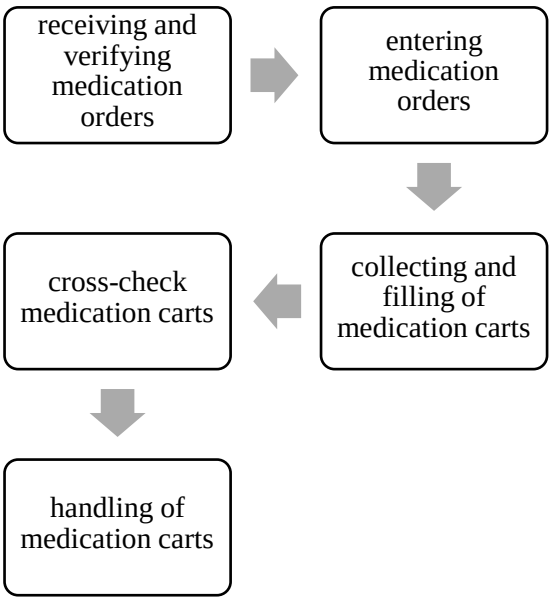


Figure 4.2 Flow chart of daily dose distribution system

- ***Inpatient dispensing process: daily dose distribution system***

1) Receiving and verifying medication orders

A medication order is defined as the desired treatment regimen provided by prescribers to be administered for a patient (Bowen, 2016). Medication orders can be handwritten, typed, verbal or entered into the computer programme and sent to the pharmacy (American Society of Health-System Pharmacists, 1993; Bowen, 2016). In this study, the pharmacists receive duplicate copies (in carbon copy form) of the original medication orders which are written by the doctors.

2) Entering medication orders by the pharmacists

The pharmacists then interpret these written medication orders and enter them into the e-hospital system. The medication orders include name of patient, name of medication, dosage expressed in the metric system, frequency of administration, and route of administration. The pharmacists print the medication orders on labels and pass them to the pharmacy technicians.

3) Collection and filling of medications cart by the pharmacy technicians

Figures 4.3 and 4.4 show that the pharmacy technicians collect those medications from the shelves which match the medication labels and then put medications for each patient into a drawer of a portable medication cart. The inpatient pharmacy receives five

medication carts in the morning and seven medication carts in the afternoon, as summarised in Table 4.1. Five pharmacy technicians have to prepare medications for 24 medication carts (12 medication carts are delivered that day and another 12 medication carts are delivered the next day). Each pharmacy technician is responsible for filling between four and six medication cards daily because they have to prepare medication carts for different wards for that day and the next day, as shown in Table 4.2.

Table 4.1 Medication carts receiving and collection time from different wards

Wards	Medication carts receiving time	Medication carts collecting time
Male Surgery Male Orthopaedic Surgery Chronic Respiratory Care Unit Trauma and Surgical Intensive Care Unit (ICU)	No later than 10.30 am	No later than 11 am
Male Internal Medicine 1 Male Internal Medicine 2 Male Internal Medicine 3 Female Internal Medicine 1 Female Internal Medicine 2 Medicine Intermediate Care Unit (MICU) Female Surgery	No later than 2 pm	No later than 3 pm

Table 4.2 Number of medications carts prepared by each pharmacy technician daily

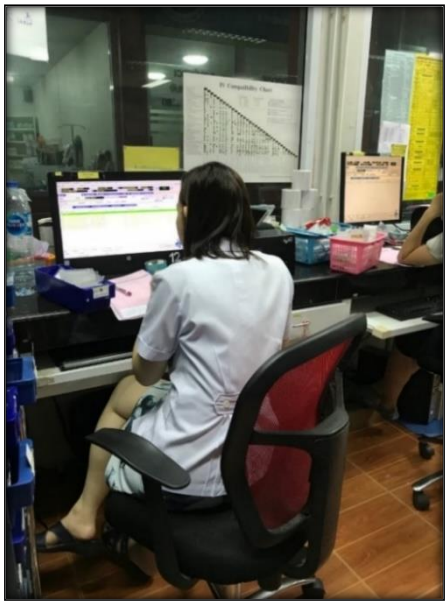
Responsibilities	Ward names	No of medication carts need to be prepared daily
Pharmacy Technician A	ICU, MICU, Male Internal Medicine 3	6
Pharmacy Technician B	Male Orthopaedic Surgery, Male Internal Medicine 2	4
Pharmacy Technician C	Chronic Respiratory Care Unit, Male Internal Medicine 1, Female Surgery	6
Pharmacy Technician D	Male Surgery, Female Internal Medicine 1	4
Pharmacy Technician E	Trauma and Surgical, Female Internal Medicine 2	4

Figure 4.3 Pharmacy technicians collect medications from the shelf

Figure 4.4 Medication cart

4) Cross-check medication carts by another pharmacist

All of the prepared medication carts are cross-checked by the pharmacists (i.e. the medication in each patient drawer of the medication cart are checked against the medication orders) before handing them to different wards (Figures 4.5 and 4.6).



Figures 4.5 and **4.6** Pharmacist checks the prepared medications against medication orders

5) Handing of medication carts

The medication carts are sent to the inpatient pharmacy no later than 10.30 am and 2 pm. The medication carts are collected by ward staff no later than 11 am and 3 pm.

4.4.2 Hospital B

The hospital aims to provide a tertiary level of health care to people in the southern provinces of Thailand. The hospital's operating capacity can accommodate up to 855 beds with over 3,000 staff and can serve up to 3,500 outpatients every day. The primary purpose of the hospital is to provide a teaching institution for medical students, nursing and public health with over 350 teaching staff personnel. The mission of the hospital is to provide services to outpatients, inpatients, accident and emergency patients.

- ***Inpatient pharmacy service***

The main clinical pharmacy activities for the inpatient pharmacy service consist of; ward rounds, medication reconciliation and drug therapy monitoring (Chaiyakunapruk *et al*., 2016). The inpatient pharmacy implements the individual medication order system to distribute medication to 38 wards across the hospital. The details of the medication distribution system are explained in the next section.

- ***Medication distribution system***

In the individual medication order system, a course of treatment is dispensed regarding the medication order for an individual patient (Management Sciences for Health, 2012). The advantage of this system is that the pharmacists can review a patient medication profile and the appropriate of treatment (Management Sciences for Health, 2012). However, the disadvantage of this system is the high number of returned medications to the inpatient pharmacy. The next sections explain the details of the inpatient dispensing process steps.

- ***Inpatient dispensing process steps***

The inpatient dispensing process steps start when the pharmacy technicians receive the medication labels until the medications are collected by the pharmacy technicians and dispensed/delivered by the pharmacists to the different wards. The five key steps of the dispensing process are explained as follows.

1) Receiving medication orders

Figure 4.7 shows that medication orders are automatically printed on labels when doctors enter medication orders into the CPOE from the wards. The CPOE allows physicians to

electronically enter medication orders, laboratory, admission and radiology (Kaushal *et al*., 2006). Three computers are used to print different types of medications: computer 1 prints the home medications and STAT medications (i.e. medications that must be administered to patients within 30 minutes, blue label); computer 2 prints the new medication ordered by the doctors and new continuous medications (green label); and computer 3 prints the continuous medications (pink label), as shown in Figure 4.8.

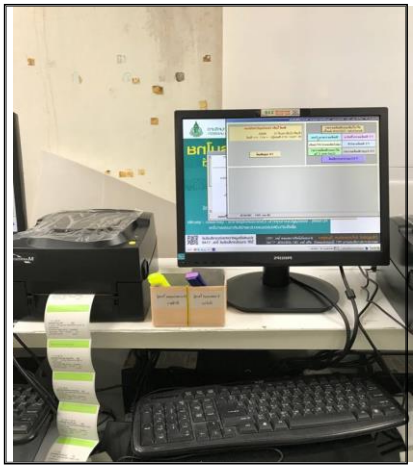


Figure 4.7 Medication labels are automatically printed

Figure 4.8 Computers used to print labels

2) Selection of medications from the shelves

After the medication labels are printed, one of the pharmacy technicians distributes the printed labels to the pharmacy technicians at the four locations (J40, J41, I38, and I39) where they can then select medications from the shelves, as shown in Figures 4.9 and 4.10. Four pharmacy technicians select tablet medications, and another two pharmacy technicians collect injection medications. Six pharmacy technicians stand at their positions and send the prepared medications to the next person, based on the list of medications on the labels. Pharmacy technicians select the medications based on the location identified on the medication labels. For example, I39Ab means that the pharmacy technician has to collect medication from location I39, column A, and row b (see Figure 4.11). The final prepared medications are put together into the three baskets based on the particular colour of medication labels: blue, green, and pink.

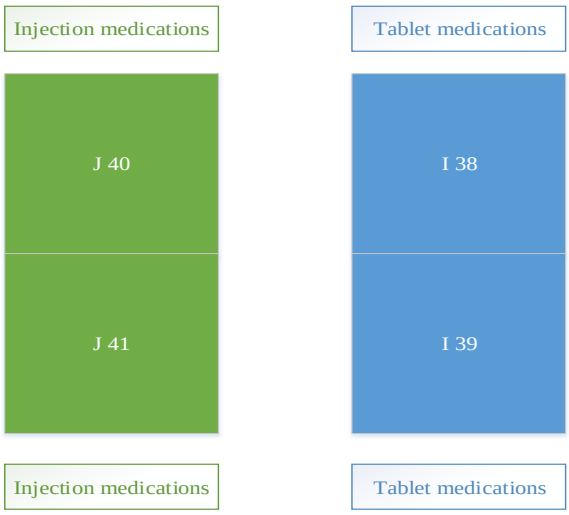


Figure 4.9 Four locations for selecting medications from shelves

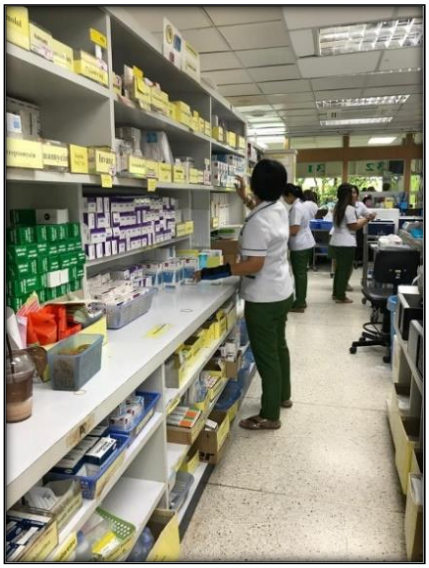


Figure 4.10 Pharmacy technicians select medications from location I39

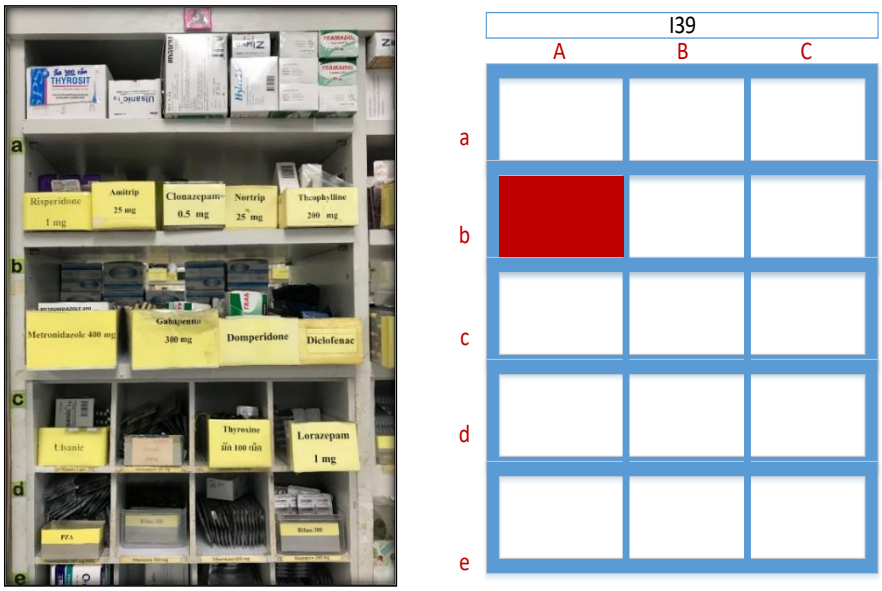


Figure 4.11 Location of medications on shelves

3) First check the prepared medications

Figure 4.12 shows the pharmacy technicians first check all the prepared medication against the labels. Then they check the blue and green medication labels, whilst another pharmacy technician checks the pink medication label. Afterwards, they move the baskets to the pharmacists to double check the prepared medications.

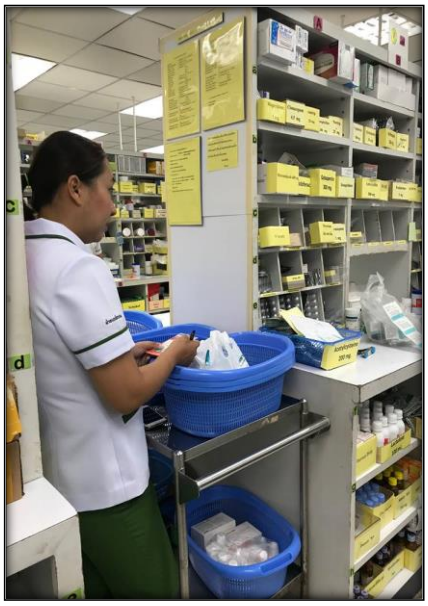


Figure 4.12 Pharmacy technician first checks the prepared medications

4) Double-check the prepared medication by the pharmacists

The pharmacists further double-check all prepared medications. The continuous medications (pink label) are double-checked by the pharmacist against the label. Home medications, STAT medications (blue label), new order medications and new continuous medications (green label) are checked by the front counter pharmacists against the medication orders from the CPOE system. If there are any questions arising from a medication order, the pharmacist must contact either a nurse/doctor to clarify the order (American Society of Health-System Pharmacists, 1993).

5) Dispensing and delivering of medications

Figure 4.13 illustrates that after the prepared medications are checked by the pharmacists, the pharmacy technicians arrange these medications in the different ward baskets. Afterwards, the prepared medications are delivered to the wards. Only home medications are dispensed by front counter pharmacists.

Figure 4.13 Ward baskets

4.5 Action Research Methodology

Action research methodology was used to solve the problems in the dispensing process in the hospitals' pharmacy division. The duration of the action research process was 10 months. This study was carried out through action research methodology that enabled the following key phases: identification of problems; reflection; planning action; taking action; evaluation; reflection; and specifying lessons learnt. Each of these is described as follows.

4.5.1 Phase 1 Identification of problems

The first phase of the action research process aims to identify the problems that lie in or between the process steps of the dispensing process which contribute to the occurrence of dispensing errors. This phase required the researcher to spend an appropriate amount of time to obtain sufficient information to identify the problems. The researcher gathered the information based on participants' perspectives (Stringer, 2007; Montgomery *et al.*, 2015) regarding the problems. The participants were asked to describe the nature of the problems based on their experiences (Stringer, 2007). In this phase, the researcher observed the dispensing process and conducted a focus group with participants to capture information about their experiences and perspectives. On completion of the focus group, the researcher fed the data back to the participants for validation. Additionally, Lean tools including process mapping and spaghetti diagram were also used in this phase to identify the problems.

4.5.2 Phase 2 Reflection

Reflection is a key component in the action research process (Koshy *et al*., 2010). Mertler (2011) pointed out that it is important for participants to engage in systematic reflection on their practice. However, it is not necessary to wait until the final stage of the action research to evaluate; reflection can be integrated throughout the action research methodology (Mertler, 2011). Therefore, in this study, the reflection occurred both during the process and in the final stage of the action research. This phase aims to reflect on the problems identified from the previous phase. These were fed back to the participants, both verbally and in writing, for consideration (Dickinson *et al.*, 2007). The researcher presented the identified problems and explained what happened in the previous phase. Following this reflection, participants decided whether the problems should be taken for further to be solved, or whether they required redefining.

4.5.3 Phase 3 Planning action

The purpose of this phase is to plan intervention tools, workshops or training sessions (Casey, 2007; Montgomery *et al.*, 2015; Sousa *et al.*, 2017) to bring about change in an existing situation (McDermott and Venditti, 2015). Waterman *et al.* (2001) conducted a systematic review of 59 action research studies undertaken in healthcare settings in the UK. In the planning action phase, the outcomes of these studies included interventions such as educational programme development and preparation for change.

In this study, training and the intervention tools were developed which aimed to facilitate change in the dispensing process in Hospital A and Hospital B. LSS was selected by the researcher as an intervention tool to solve the identified problems. The participants were trained by the researcher to understand the principles of LSS and its associated tools and techniques, and to develop an understanding in the use of the appropriate tools and techniques.

4.5.4 Phase 4 Taking action

LSS was implemented through collaboration between the researcher and participants. The researcher acted as a facilitator and consultant to help the participants apply DMAIC methodology. The team followed DMAIC methodology to solve the problems in the dispensing process and improve the performance of the dispensing process. Table 4.3 summarises tools and techniques that were used in each phase of the DMAIC methodology.

Table 4.3 Lean and Six Sigma tools and techniques used in DMAIC methodology

Six Sigma methodology	Goals	Tools	Output
Define	To define the problems in the dispensing process that need to be improved	Process mapping Spaghetti diagram Project charter In frame/Out frame	The identification of problems that need to be solved.
Measure	To identify the baseline performance of the dispensing process	Data collection plan Pareto chart P- control chart	The baseline performance of the dispensing process
Analyse	To identify the root cause of the problem	Cause and effect analysis Multi-voting 5 why analysis	The root cause of the problems
Improve	To develop and implement solutions to minimize the effect of the root causes identified from the previous phase	Brainstorming Visual control management Process balancing	The potential solutions
Control	To maintain the improvement of the process over a period of time	Standard operating procedure P- control chart Hypothesis testing	Standard operating procedures of the new methods

4.5.5 Phase 5 Evaluation and Reflection

This phase aims to evaluate the effectiveness of LSS interventions which were implemented to solve the problems in the dispensing process. The participants who have most to benefit from an improvement in their practice are encouraged to evaluate the outcome of change resulting from the implementation of intervention (Winter and Munn-Giddings, 2001). In this study, the participants were required to evaluate the outcome of change resulting from the implementation of LSS, and to identify challenges and critical success factors of LSS deployment. The participants were required to provide feedback from the LSS training regarding its tools and techniques that were applied in each phase of the DMAIC methodology. In addition, the participants were asked about the knowledge they had gained from the execution of the action research project.

4.5.6 Phase 6 Specifying lessons learnt

The lessons learnt encompass "the learning gained from the process of performing the project" (PMI, 2004, p.363). These can include both the positive and negative aspects which participants have experienced during the project (Rowe and Sharon, 2006). In the

last stage of the action research methodology, the participants were required to identify their lessons learnt from the execution of the action research project. This can then be used to improve the next cycle of the action research process.

4.6 The roles of researcher and relationship with participants

From the beginning, the researcher acted as a facilitator and consultant to facilitate the implementation of LSS in the inpatient pharmacy in Hospitals A and B. The researcher developed a range of skills such as effective planning, observation, and critical reflection during the action research methodology (Koshy *et al*., 2010) and introduced LSS to improve the dispensing process (McDermott and Venditti, 2015). Moreover, it is important for the action researcher to encourage participants to examine their own problematic situation (Winter and Munn-Giddings, 2001). In this study, the researcher developed a robust methodology to ensure that the participants provided sufficient information and actively engaged in all phases of the action research methodology (Algeo, 2013; Sousa *et al*., 2017).

At the beginning of the project, the researcher presented the objectives of the implementation of the action research methodology, the participants' role and how to collect the data in each phase of action research (Waterman *et al*., 2005b). The participants were motivated by the researcher to ensure that all felt that this project was useful and can change their practice. Moreover, successful case studies of LSS employment in the healthcare sector were presented to the participants. The researcher also provided the project timeline to participants to ensure that they were available to participate in all phases of the action research.

The participants were able to share their experiences and perspective regarding the relationship developed with the researcher throughout the action research (McGinn, 2008). The relationship between the researcher and participants could influence the quality of the research outcome (Algeo, 2013). One of the first steps to establish the researcher-participant relationship is to select appropriate participants and secure their agreement to become a part of the action research project (Algeo, 2013). To establish trust, as mentioned in Chapter 3 in the ethical considerations section, the researcher used a participant information sheet and informed consent document which emphasised confidentiality and anonymity beyond the action research setting. When the project was conducted, participants felt free to negotiate or discuss with the researcher and the researcher always helped them to feel comfortable. Moreover, a trusting relationship

between researcher and participants was maintained in order to ensure that the change in their dispensing process would not affect their routine work.

4.7 Participants

A purposive sample of participants who have worked and were involved in the dispensing process were approached to take part in this study (Waterman *et al*., 2005b; Casey, 2007). All participants in Hospitals A and B were female and were employed full time. A systematic review of action research studies undertaken in a hospital setting was conducted by Montgomery (2015), and the review showed that the number of participants participating in action research ranged from seven to 260. Sargeant (2012) pointed out that the number of participants is based on their ability to provide important information regarding the phenomenon being studied. In this study, for Hospital A, the participants included three pharmacists, three pharmacy technicians, and the Head of Inpatient Pharmacy, as presented in Table 4.4. For Hospital B, the participants included the pharmacist, three pharmacy technicians, the Head of Pharmacy Department, the Head of Pharmacy Service, and the Head of Inpatient Pharmacy, as shown in Table 4.5. The number of participants in this study was also reported in other studies such as Casey (2007) and Algeo (2013). In addition, the criteria for choosing participants included:

1) participants who can provide the richest and most complex source of data that are relevant to the phenomena being studies;
2) participants who have worked and have experience in relation to the dispensing process.

Table 4.4 Participants demographics, Hospital A

Sex	Years of experience	Positions
Female	3	Head of Inpatient Pharmacy
Female	18	Pharmacist
Female	3	Pharmacist
Female	2	Pharmacist
Female	16	Pharmacy technician
Female	12	Pharmacy technician
Female	7	Pharmacy technician

Table 4.5 Participants demographics, Hospital B

Sex	Years of experience	Positions
Female	22	Head of Pharmacy Department

Female	21	Head of Pharmacy Service
Female	10	Head of Inpatient Pharmacy
Female	20	Pharmacist
Female	13	Pharmacy technician
Female	15	Pharmacy technician
Female	15	Pharmacy technician

4.8 Data collection methods

A range of methods was used to collect the data in each phase of the action research including observation, focus group, field notes, and interviews. The following sections explain how each method of data collection was conducted in different phases.

A. Observation

Observation helps to identify the origin and location of the problems and understand problems in the first instance (Arumugam *et al.*, 2012). The researcher decided to be a participant observer and adopted a structured observation. The researcher used an observational schedule as a guideline for data collection before entering the field.

In the problem identification phase, the researcher observed the current process of medication dispensing to understand how medications were dispensed from the first step until the inpatients received the medications. The researcher observed the workflow, staff's actions, and behaviours and how they worked and interacted. Table 4.6 shows the observational schedule consisting of different topics of interest which guided the researcher during the observation. The researcher undertook the observation of the dispensing process for both hospitals for one month, during the normal working hours (9.00 am - 4.30 pm).

Table 4.6 Observational Schedule

Date Time	
Topics of interest	**Notes**
How many steps are in the dispensing process?	
What happened in each step of the dispensing process?	
What forms of waste are occurring between end-end dispensing processes?	

What are staff's actions and behaviours?

During observation, the data were captured and recorded in the field notes without any bias based on previous knowledge and background of the researcher. In addition, in the taking action phase, the researcher observed the situation and took field notes to gather all of the data related to the implementation of LSS in the dispensing process.

B. Focus group

In the first phase of the action research, the focus group was conducted to identify the problems in the dispensing process. The focus group enabled the researcher to bring participants together to discuss their opinions and perspectives based on their experiences in the inpatient pharmacy. The focus group consisted of seven participants (Montgomery *et al.*, 2015), and lasted 90 minutes. The researcher started the focus group with an introduction, followed by setting the ground rules and explaining the procedures of focus group to the participants. Participants were asked the following questions:

1.What are the problems that lie in the process steps and the linkage between the process steps that can contribute to dispensing errors?

2. Which process steps can contribute to the higher numbers of dispensing errors?

3. When does the problem occur; are there certain days/times?

4. What tools do you use at the moment in tackling dispensing errors?

5. Do you measure dispensing errors per week and if so, are any tools used to monitor them over a period of time?

6. How do you make sure that these dispensing errors do not occur again? Do you have any control plans in place to prevent these errors?

During the focus group, the researcher also recorded physical behaviour of participants and took field notes. At the conclusion of the focus group, key points were summarised and further verified by the participants (Moxham *et al*., 2010). The focus group discussions were audio-taped, transcribed verbatim, checked for the accuracy by the researcher and presented to the participants (Waterman *et al*., 2001; Moxham *et al*., 2010).

C. Field notes

The researcher used field notes to record the details and descriptive information when observing the dispensing process (Brodsky, 2008; Creswell and Plano Clark, 2011). The

field notes were used in every phase of the action research. It was used to support information obtained from the interview and focus group (Phillippi and Lauderdale, 2018). The researcher also used field notes to collect all the activities in the dispensing process and direct quotes from the staff in the inpatient pharmacy. The researcher separated the field notes into two main sections (Mulhall, 2003; Brodsky, 2008; Phillippi and Lauderdale, 2018):

- Observation
  - Descriptions of the event on a day-to-day basis
  - Physical setting (the environment, detail of inpatient pharmacy)
  - Behaviours and activities of staff in the dispensing process (how they work and how they interact with each other, comments from the participants)
  - Any difficulties that the researcher encountered.

- Personal reflection information
  - How the researcher felt and reacted to the events
  - What the researcher had learned from the experience, how and why things happened
  - Reflections on the researcher's own feelings of the process and participants

The researcher wrote the notes shortly after seeing or hearing something interesting that was thought to be useful for the research (Mulhall, 2003). Every day after the researcher left the field, the notes were recorded on a personal computer.

D. Interviews

Semi-structured interviews were conducted in the 'evaluation and reflection' and 'specify lessons learnt' phase. The researcher carried out an individual interview with participants to evaluate the outcome of LSS implementation and to explore how participants felt about the project and their lessons learnt. The interview focused on how participants perceived change in the dispensing process after the implementation of LSS, thoughts about LSS methodology and its tools and techniques, challenges and critical success factors of using LSS in the dispensing process, lessons learnt, and knowledge gained from the project.

Each participant was asked the same set of questions by the researcher based on open-ended questions to express their feelings, perspectives, and opinions after the implementation of LSS through the action research. Each interview was carried out in the

meeting room in the inpatient pharmacy and lasted approximately 60-90 minutes. The researcher asked each participant for the permission to record and take notes (Collis and Hussey, 2014). After the interviews with some participants, the researcher had reached data saturation as no new information was received (Saunders *et al*., 2016). The researcher arranged to undertake the interview with each participant at a time convenient to the interviewee. In order to generate robust and valuable data, the interview was conducted following the interview guide suggested by O'Gorman and MacIntosh (2015), as summarised in Table 4.7.

Table 4.7 Interview guide

Activity	Description
Selecting the setting	The researcher conducted each interview in the meeting room in the inpatient pharmacy.
Recording	The researcher asked each participant for the permission to record the interview and take notes.
The interview guide	The researcher prepared a set of questions covering all information related to the evaluation, reflection and lessons learnt from the action research project. Probing questions were also asked to gain more information (Collis and Hussey, 2014), for example, 'Can you explain again?', Can you give me an example?'and 'What do you mean?'
Non-verbal communication	The researcher took note of nonverbal information during the interview with participants such as body language and facial expression.

Source: adapted from O'Gorman and MacIntosh (2015)

The participants were asked the following questions:

1. Has the dispensing process changed since the intervention of the researcher in the pharmacy department using LSS methodology and if so, please can you say in what ways?
2. What are your thoughts about DMAIC methodology and its application in the dispensing process?
3. Are you convinced that LSS can be applied to the dispensing process? If so, what are the primary reasons for not applying this methodology before in the pharmacy department?
4. What are the challenges of using LSS in the dispensing process?

5. Which sets of tools used in the dispensing process have proved to be useful and why?
6. Has your knowledge about tools of LSS been improved? If yes, how?
7. What knowledge has been generated from the intervention of the researcher in the hospital?
8. What are the major lessons learnt from the project?
9. Do you plan to use more LSS projects in the hospital and if so, what areas can be targeted in your personal experience?
10. What factors should be considered for the successful implementation of LSS in the hospital?

The above questions were validated by the supervisory team in the University and two pharmacists from Hospital A and Hospital B.

E. Questionnaire

A questionnaire was used in the evaluation phase to measure the patient's satisfaction with the quality of pharmacy services before and after the implementation of LSS. The questionnaire was derived from a review of existing inpatient satisfaction questionnaires (Arab *et al*., 2014; Salehi *et al*., 2017; Meesala and Paul, 2018). The questionnaire design is explained in Chapter 3 section 3.8.

4.9 The quality of action research

The quality of research in the natural sciences and quantitative research in the social sciences are judged by considering the reliability and validity (Saunders *et al*., 2016). Several authors have claimed that action research does not have specific criteria to judge the quality of research compared to quantitative approaches such as survey and experimental design (Farooq and O'Brien, 2015; Coghlan and Brannick, 2005). However, the action researcher can use alternative criteria to access the quality of the research inquiry or may adapt the criteria of reliability and validity to the research (Saunders *et al*., 2016). Action research can identify its own quality criteria and should not be judged by the positivist and naturalistic criteria (Coghlan and Brannick, 2005; Herr and Anderson, 2005), as action research seeks to create change and solve the problems in practice. Action research requires criteria that can explain how well its outcome leads to the improvement of the specific situations (Feldman, 2007). Heikkinen *et al.* (2007) proposed four quality criteria in action research as follows.

1. Principle of historical continuity

   Action research should report the events in time order and logical consequences.
2. Principle of reflexivity and dialectics.

   The researcher should examine the relationship with the participants and the report should present the different voices and interpretations.
3. Principle of workability

   "How well does the outcome of the research succeed in creating workable practice?" (Heikkinen *et al*., 2017, p.9)
4. Principle of evocativeness

   "How well does the research narrative evoke mental images, memories or emotions related to the theme?" (Heikkinen *et al*., 2017, p.9)

Herr and Anderson (2005) adopted the term validity in a specific way, proposing five criteria which were linked to the goal of action research, as presented in Table 4.8.

Table 4.8 Herr and Anderson's goals of action research and validity criteria

Goals of Action Research	Quality/Validity criteria
The generation of new knowledge	Dialogic and process validity
The achievement of action-oriented outcomes	Outcome validity
The education of researcher and participants	Catalytic validity
Results that are relevant to the local setting	Democratic validity
A sound and appropriate research methodology	Process validity

Source: Her and Anderson (2005)

The details of each criteria are as follows.

1. Dialogic and process validity mean that the research is exposed to critical and reflective dialogue with other researchers who can suggest alternative interpretations of the research data.
2. Outcome validity refers to the action occurring which could solve the problem and lead to the success of the project.
3. Catalytic validity refers to the researcher and practitioners achieving a deeper understanding of the social setting being studied.
4. Democratic validity refers to which research is done in collaboration with all participants involved in the problem under investigation.
5. Process validity refers to the effectiveness of the research methodology to address the research problem.

Heikkinen *et al*. (2007)'s discussion of quality criteria overlaps to some extent with criteria presented by Herr and Anderson (2005). Furthermore, Reason (2003) introduced sets of questions dealing with every type of action research. In this study, the researcher adapted the criteria proposed by Herr and Anderson (2005), Heikkinen *et al.* (2007) and Reason (2003) to ensure the quality of the action research as follows:

1. The researcher told the story of the events in a logical order and provided reflections on the story. The story was recorded in field notes and the researcher's diary (Heikkinen *et al*., 2007; Coghlan and Brannick, 2005).
2. The researcher took action by introducing LSS into the inpatient pharmacy, with training, which led to a reduction in dispensing errors and the implementation of several changes in the dispensing process (Heikkinen *et al*., 2007).
3. The researcher observed the inpatient pharmacy and then took note to understand of the social setting being studied (Herr and Anderson, 2005).
4. The researcher collaborated with participants throughout the project (Herr and Anderson, 2005).
5. The researcher developed a robust action research model, which is presented in Chapter 3 to addressing the research problem. The rigorous description of the action research, research context and data collection methods are clearly explained in Chapter 4 which can help others to replicate the study in similar contexts.
6. Practical and theoretical knowledge were generated from action research.
7. The implementation of LSS through the action research methodology led to the improvement of the dispensing process, reduction of dispensing errors and patient safety improvement (Heikkinen *et al*., 2007; Herr and Anderson, 2005). Action research findings from Hospital A and Hospital B are presented in Chapter 5 and Chapter 6.

In addition, the above criteria cover all four characteristic dimensions of action research identified by Reason (2003), including addresses practical problems, encompasses many ways of learning, a participative and democratic process, and an emergent process.

4.10 Chapter summary

The chapter has explained the key characteristics of action research, showing how such characteristics were applied in the research. The details of the two hospitals and its inpatient pharmacy and dispensing process were provided. The key phases of the action research methodology were explained, followed by the details of data gathering used in

the action research. The criteria used to assess the quality of action research were discussed. The next chapter presents the key findings from the action research methodology undertaken in the inpatient pharmacy in Hospital A.

CHAPTER 5 – ACTION RESEARCH FINDINGS FROM HOSPITAL A

5.1 Introduction

The purpose of this chapter is to present the findings from the action research study which was undertaken in the inpatient pharmacy in Hospital A. For the daily dose distribution system, the findings are presented following the key phases of the Action Research model developed in Chapter 3. In **Phase one**, the key problems in the dispensing process are identified. **Phase two** is involved with reflection on the identified problems. **Phase three** is related to the planning of an intervention and participants attending the LSS training. The action research team further implemented LSS in **Phase four**. Following the implementation, the project is evaluated and reflected upon by the participants **in Phase five**. The lessons learnt as perceived by the participants are identified in **Phase six**. Following the three days dose distribution system, the findings from Lean methodology are presented. Challenges and critical success factors for the implementation of LSS in the inpatient pharmacy as perceived by the participants are further identified. Finally, reflections and key lessons learnt by the researcher regarding the research process throughout all phases are presented.

5.2 Case study on action research methodology: Hospital A

The following section presents the key findings from the action research undertaken in the daily dose distribution system. The findings are presented based on the key phases of action research: identification of problems, reflection, planning action, taking actions, evaluation and reflection, and specifying lessons learnt. Subsequently, the key findings from the employment of Lean methodology to reduce patients' relatives waiting time in three days dose distribution system are presented.

5.2.1 Daily dose distribution system

Phase 1: Identification of problems

After the completion of the focus group and using Lean tools including process mapping and spaghetti diagrams, two main problems were identified:

(1) Pharmacists can enter medication orders incorrectly into the e-hospital system, and

(2) Pharmacy technicians can select medications incorrectly.

The incorrect entry of medication orders and the incorrect selection of medications were the main process problems that created dispensing errors. The next section provides the details of such problems.

Problem 1: Incorrect entry of medication orders

A high number of dispensing errors were caused by pharmacists entering medication orders incorrectly into the e-hospital system. This is illustrated by the following views expressed by pharmacy technicians and a pharmacist:

> *'Medication orders entered incorrectly was the main step that contributed to a higher number of dispensing errors'. (Focus group, pharmacy technicians)*

> *'Dispensing errors occurred from the first step which was entering medication orders into the e-hospital system. If there were a high number of medication orders entered incorrectly, there were more opportunities for me to dispense the wrong medications, the wrong quantity, etc. to the patients'. (Focus group, Pharmacist)*

One of the pharmacists who was entering medication orders while I was observing the dispensing process described his experience as follows:

> *'While I was working (entering medication orders into the system) I always found errors such as doctors who did not write the patient's name and newly graduated doctors using medication abbreviations'. (Field notes)*

The process of entering medication orders is complex. Each pharmacist enters medication orders for three wards. This contributed to pharmacists entering them incorrectly. The staff reflected on this process:

> *'The process steps of entering medication orders were so complex. While I was entering medication orders, there were more medication orders delivered to me from the wards after the medication carts had been delivered. When more medication orders came to me, it distracted me and made me lose concentration about what I was doing'. (Focus group, Pharmacist)*

> *'Ward round by doctors were not on time which resulted in medication orders being sent to the pharmacists all the time. Therefore, this contributed to the errors in entering medication orders'. (Field notes)*

Problem 2: Incorrect medication selection by pharmacy technicians

Pharmacy technicians collected and filled the medication carts based on medication labels of each patient. Incorrect medication selection from shelves was another problem, leading to the occurrence of dispensing errors. One participant stated this explicitly:

> *'The pharmacy technicians worked quickly (collecting medications and filling carts) because of time constraints. This process step could lead to a high number of dispensing errors'. (Focus group, Pharmacist)*

> *'In my opinion, selection of medication contributed to the most frequent of dispensing errors. The errors related to medication selection occurred daily'. (Field notes)*

Any errors from the medication selections' process could potentially harm patients. However, these errors often remained undetected by pharmacists. One of the pharmacists explained:

> '*If the pharmacy technicians do not follow the medication preparation standard procedure, a high number of errors could pass to me, but sometimes these errors were undetected by me and could harm the patients'. (Focus group, Pharmacist)*

The pharmacy technicians described that the errors resulted from poor system design and the complex medication selection process.

> *'The errors from medication selections resulted from the poor system design'. (Field notes)*

> *'There were many steps in the medication preparation process. We had used this system for many years'. (Field notes)*

> *'I had to collect medications and fill the medication carts and, at the same time, there were more medication orders being sent to me. This could contribute to errors'. (Field notes)*

The participants were aware of these problems in the inpatient pharmacy. They had been trying to solve these problems, but the problems remained in the process. For example, 'look alike sound alike' medications had been placed separately on shelves. Expired medications had been checked by the pharmacists every month. When the dispensing

errors occur, the pharmacists arranged a meeting, identified the causes of each incident and found solution/s. The following extracts from field notes during observation illustrate this point:

> *'We used to arrange a meeting aiming to reduce the errors from medication selection and entering medication orders. However, it was not successful'.*

> *'We used to try to tackle the problem of incorrect medication selection, but the problem still remains unsolved'.*

The identified problems were further reflected upon by participants in the next phase in order to make a decision about the problems could continue to be resolved or would need to be redefined based on the action research model developed in Chapter 3.

Phase 2: Reflection

In this phase, the researcher presented a spaghetti diagram and process mapping and explained each tool in detail to participants. The process mapping allows the team to identify the process steps that impact the medication process performance (Antony *et al*., 2016). The project team can identify the areas where there is unnecessary movement by analysing the lines that are evident when the spaghetti diagram is applied (George *et al*., 2005). More details of such tools are explained in the 'taking action' phase. The researcher further presented the problems identified from phase 1 to participants. The participants agreed that they were the identified problems and indicated that they would like to solve them as soon as possible. The team decided to focus on entering medication orders and preparing the medication process steps, as these problems had the biggest impact on patient safety. Participants stated that:

> *'These problems had been discussed for many years, but never resolved'. (Field notes)*

> *'We (pharmacists) would like to change the system in order to reduce our workload. Then, we could have more time to do other jobs'. (Field notes)*

Discussion with participants resulted in an enthusiasm to make changes in the dispensing process. In order to facilitate change in the dispensing process, LSS training and intervention tool were developed in the next phase.

Phase 3: Planning action

This phase aims to plan an intervention by ascertaining which interventions would be used to solve the problems identified in the first phase. Based on the action research model in chapter 3, the key question to ask, having decided to implement LSS methodology to solve the identified problems, was as follows:

(1) Are the solutions unknown and, at the same time, is there an element of variation and waste?

Based on the question, the solutions for the identified problems were unknown. The participants had implemented several approaches such as ensuring proper storage of medications, use of Tall Man lettering to emphasise sound-alike medications, adding warning signs for look-alike medications and promoting awareness among healthcare providers on good dispensing, but the problems remained and could not be resolved. Variation also existed in a control chart, which was presented in the taking action phase. In addition, there were several non-value added activities in the dispensing process such as rework, unnecessary movement of staff and waiting for medication orders. Lean tools can be integrated in Six Sigma methodology, and all action plans required the application of LSS methodology.

The researcher conducted three hours of LSS training in the inpatient pharmacy. The training had an open invitation and two pharmacists who were not members of the action research team also attended (Waterman *et al*., 2005b). The training commenced with the principle of Lean thinking and forms of waste in the process. Then, the researcher introduced Six Sigma and LSS philosophy. The researcher further explained the basic tools and techniques of Lean and Six Sigma (e.g. control chart, VSM, Pareto chart, 5 Why analysis, and cause and effect analysis), the DMAIC methodology, the benefits, challenges, and CSFs of LSS implementation in healthcare.

The researcher also presented examples of LSS implementation case studies which resulted in successfully reducing medication errors. In addition, two published articles: 'Can Lean Six Sigma be used to reduce medication errors in the health-care sector?'(Trakulsunti and Antony, 2018) and 'Reducing medication errors using LSS Methodology: a systematic literature review and key findings' were distributed to the participants (Trakulsunti *et al*., 2018). After training, the aim was that participants would understand LSS, the basic quality and process improvement tools and DMAIC

methodology for problem-solving, the CSFs, the benefits and challenges of LSS implementation in healthcare. The researcher collaborated with participants to develop action plans to achieve solutions to the problems identified from the first phase (Nilvarangkul *et al*., 2016), as presented in Table 5.1. After that, all plan activities were implemented in the next phase.

Table 5.1 LSS methodology planning actions

Problems	LSS Methodology	Start	Finish
Incorrect selection of medications	Define Phase	21 Mar 2018	30 Apr 2018
	Measure Phase	1 May 2018	30 Jun 2018
	Analyse Phase	1 Jul 2018	31 Jul 2018
	Improve Phase	1 Aug 2018	31 Dec 2018
	Control Phase	1 Jan 2019	31 Dec 2019
Incorrect entry of medication orders	Define Phase	21 Mar 2018	24 Apr 2018
	Measure Phase	25 Apr 2018	25 Jun 2018
	Analyse Phase	26 Jun 2018	23 Jul 2018
	Improve Phase	24 Jul 2018	31 Dec 2018
	Control Phase	1 Jan 2019	31 Dec 2019

Phase 4: Taking action

The project team followed the DMAIC methodology and applied several LSS tools and techniques to each phase of the methodology.

1) Define Phase

The define phase aims to identify the scope and goals of the projects (Gijo *et al.*, 2013; Bhat *et al*., 2014) in addition to the problems associated with the process that needs to be improved. A project team was formed to include a researcher, the Head of Inpatient Pharmacy, three pharmacists, and three pharmacy technicians. Firstly, a project charter clarified team member roles and responsibilities and helped the team to focus on the project goals. This charter captured basic project details, including the problem statement, project scope, goal, and schedule (Table 5.2).

Table 5.2 Project charter

Project Charter	
Customer(s)	**Customer CTQ**
Inpatients	Number of dispensing errors
Problem Statement	**Potential Benefits**
Dispensing errors occurred daily especially in the busy period in the inpatient pharmacy. The average number of dispensing errors that could not be detected by the pharmacists between March 2017-March 2018 was 23 errors. The dispensing errors could lead to patient injury and death and contribute to an increase in hospital costs.	Reduce dispensing errors, improve patient safety and staff satisfaction
Goal Statement	**Project scope**
The goal is to reduce the number of dispensing errors in an inpatient pharmacy by 50%.	The pharmacies received the medication orders and medication cards are delivered to different wards.
Schedule	**Potential Team Members**
Phase **Start** **Finish** Define Mar 2018 Apr 2018 Measure May 2018 Jun 2018 Analyse Jul 2018 Jul 2018 Improve Aug 2018 Dec 2018 Control Jan 2019 Dec 2019	Team leader: Researcher Team members: Head of Inpatient Pharmacy Pharmacist 1 Pharmacist 2 Pharmacist 3 Pharmacy technician 1 Pharmacy technician 2 Pharmacy technician 3

In the next step, an In Frame/Out of Frame tool was used to ensure that the project had a clear scope (Figure 5.1). The tool helped the team to have a clear understanding of the project scope.

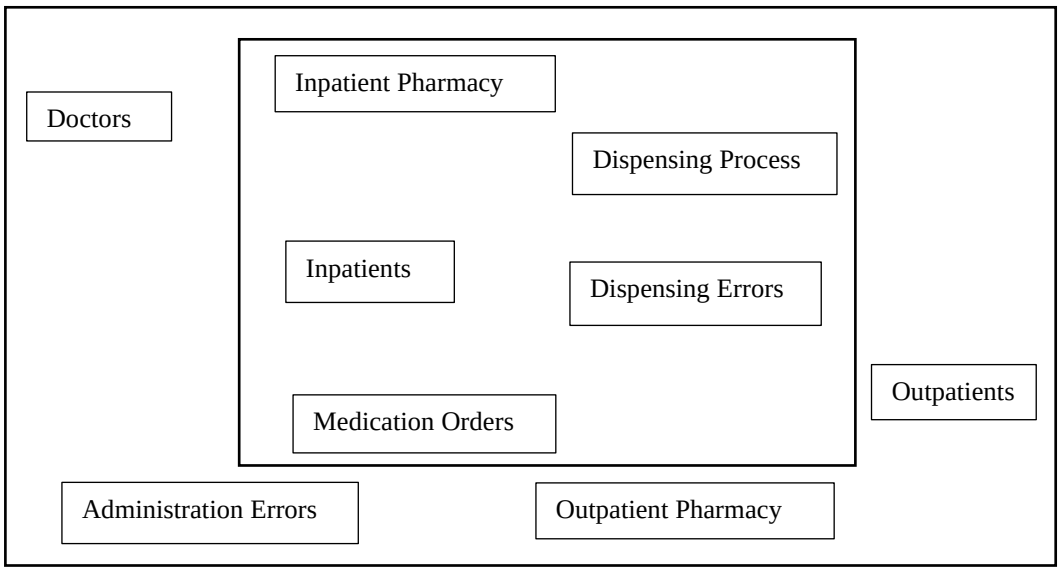


Figure 5.1 In Frame/Out of Frame tool

The team further used Lean tools including spaghetti diagram (Figure 5.2) and process mapping (Figure 5.5) to identify inpatient pharmacy dispensing process improvement opportunities. The next section explains the detail of the spaghetti diagram and process mapping, followed by the problem statement showing the impact of the problems.

Spaghetti diagrams

The team applied a spaghetti diagram to trace the movement of pharmacy technicians. The researcher decided to observe the movement of pharmacy technicians from 8.30 am – 4.30 pm. The researcher printed out the floor plan of the pharmacy service area and drew the actual movements of five pharmacy technicians. The spaghetti diagram illustrates the excessive movement of pharmacy technicians in the inpatient pharmacy. These unnecessary movements arose when more medication orders from the wards were sent to the pharmacy technicians after the medication cards had been delivered to wards. The pharmacy technicians walked back and forth from their workspaces to deliver more medications to the front counter staff. During the day, pharmacy technicians had to collect more medications that had not been sent within the medication card delivering time. More medication orders were put in baskets for each patient (Figure 5.3). After that, the pharmacy technicians walked back and forth from their workspaces to deliver more medications to the front counter staff. The pharmacists further dispensed these medications to inpatients' relatives (Figure 5.4).

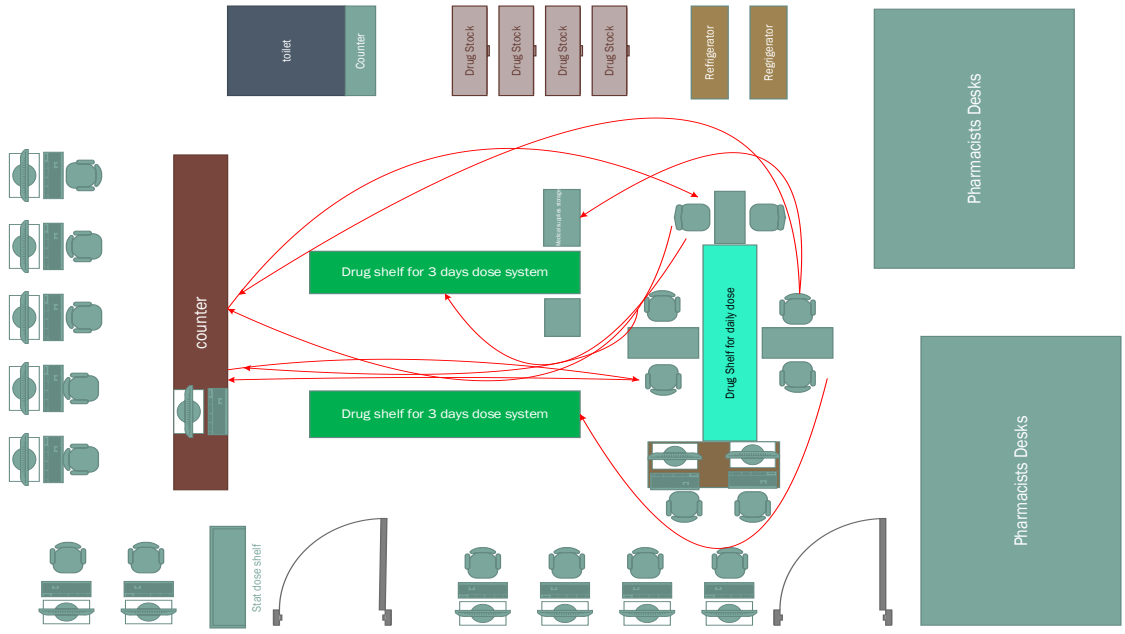


Figure 5.2 Spaghetti diagram showing the unnecessary movement of pharmacy technicians

Figure 5.3 More medication orders from wards

Figure 5.4 Front counter

The pharmacy technicians were wasting their time collecting and filling more medication orders from wards. The additional medication orders interrupted pharmacy technicians while they were preparing medications.

Process Mapping

As process mapping graphically represents process activities, it aids the identification of the existing process steps and the redundancy in the dispensing process. At the beginning of creating a process map, the Head of Inpatient Pharmacy and the researcher walked in both directions through the dispensing process (backwards and then forwards) twice a day in order to understand what had occurred in each of the process steps. During the walks, the researcher also examined how medication flowed from one workstation to the next. The researcher observed the activities and talked to the staff who were involved in each process step. Then, the researcher collaborated with the participants to create an as-is dispensing process mapping. This process map includes six mains steps:

1) Pharmacists receive and verify medication orders;
2) Medication orders are entered into the e-hospital system;
3) Medication orders labels are printed;
4) Pharmacy technicians collect and put the medications into dedicated medication cart drawers for each patient;
5) A pharmacist who did not enter the orders cross-checks medications; and
6) Medication carts are delivered to the wards.

The team reached an agreement on the process steps that were contributing to the dispensing errors. These included problems in medication orders entered by pharmacists, and the collection and filling of medication by pharmacy technicians. One pharmacist stated:

> *'I was frequently interrupted when I entered medication orders into the system'. (Field notes)*

The pharmacy technicians claimed that filling medication resulted in a high number of dispensing errors.

> *'Collecting and filling medications was a very complex process. I had to do many steps to finish my work'. (Field notes)*

> *'I think collecting medications was a main problem resulting in dispensing errors. I quickly collected and filled medications in order to finish on time'. (Field notes)*

There were also unnecessary rework loops when pharmacists encountered illegible handwriting of doctors. The main reasons for illegible handwriting were because of the use of a trade or brand name instead of the generic name and the use of abbreviations for the medication name. They had to spend a lot of time consulting with nurses or doctors to clarify medication orders. Once the order was resolved, the pharmacists entered medication orders into the system. Another rework loop occurred when pharmacists counterchecked the medications and found that there was a difference between medication prepared by pharmacy technicians and the written medication orders by doctors. Pharmacy technicians had to change medications and collect the right one.

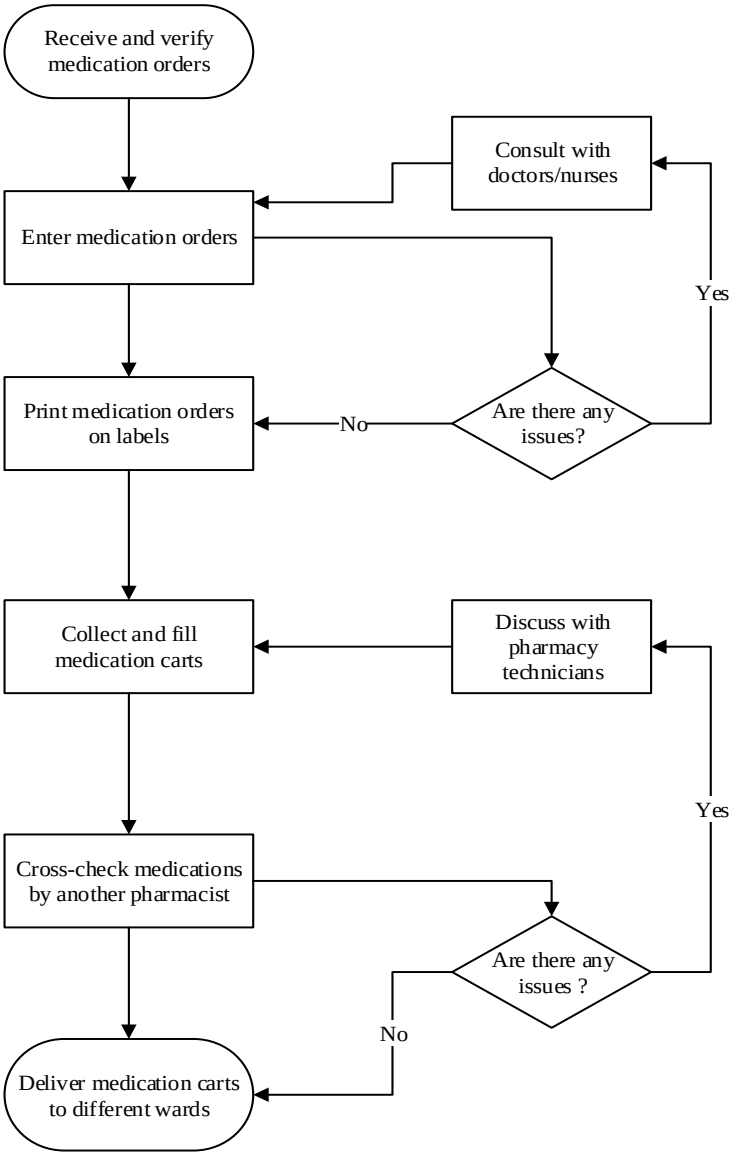


Figure 5.5 A flow map of dispensing process for daily dose distribution system

Problem statement

A problem statement is developed to define and understand the problems based on facts and data. To define the problems, the problem statements matrix was used as an outline (see Tables 5.3 and 5.4). The detailed problem statement specified that incorrect entry of medication orders and incorrect selection of medications which occurred daily, particularly during busy periods (10 am - 12 pm and 2 - 4 pm). The identified process problems needed to be improved to reduce medicine dispensing process variation, mitigate patient harm, and hospital costs and financial risk.

Table 5.3 The problem (incorrect entry of medication orders) statement matrix

Questions	Explanation
What is wrong?	The pharmacists interpreted the medication orders differently from the prescribed medications. The pharmacist incorrectly entered medication orders into the system.
Where does the problem appear?	In the dispensing process
When does the problem appear?	Daily especially in the busy periods
How big is the problem?	This problem could lead to incorrect medication selection, which could contribute to harm or even to death of the patient.

Table 5.4 The problem (incorrect selection of medications) statement matrix

Questions	Explanation
What is wrong?	Pharmacy technicians collected incorrect medications from the shelves and put these into the medication carts.
Where does the problem appear?	In the dispensing process
When does the problem appear?	Daily especially in the busy periods
How big is the problem?	Patient injury and death can occur with financial costs to the hospital.

2) Measure Phase

This phase aims to translate problems into measurable forms. Current process data was gathered to establish the medication dispensing process baseline performance (Gijo and Antony, 2014; Sanders and Karr, 2015). A data collection plan was developed to ensure that the team collected appropriate and reliable data (Table 5.5) (George *et al*., 2005). The team used dispensing errors as the measured CTQ characteristics, defining this as the medication errors undetected by inpatient pharmacy pharmacists. Afterwards, the team divided the measure into process measure and output measure to assess the baseline performance of the dispensing process. The process measure included the errors that occurred in the process steps which were detected by the pharmacists. The number of errors in medication selection and medication entering were collected for this measure.

The output measure included the errors that occurred at the end of dispensing process which were undetected by the pharmacists. The undetected dispensing errors were collected for this measure.

Table 5.5 Data collection plan

Metric	Type of Measure	Type of data	Operational definition	Source of data	Collection method
Detected dispensing errors	Process	Discrete (counts of errors)	The errors that occurred in the process step that were detected by the pharmacists.	Using existing data	Medication Error Incident form completed
Undetected dispensing errors	Output	Discrete (counts of errors)	The errors that occurred at the end of dispensing process which were undetected by the pharmacists	Using existing data	Nurses report to Hospital Risk Management system.

For process and output measure, the team was able to use the existing data which were recorded by participants. For process measure, the pharmacists used the medication error incident form to collect the number of errors in medication selection and medication entering. At the end of each month, two pharmacists manually recorded the number of errors in medication selection and medication entering on an excel spreadsheet. The recorded data included frequency of errors, types of errors and ward name. Interestingly, these existing data were never used to assess the performance of the dispensing process. Even though the number of dispensing errors was collected every month, the pharmacists did not use any tools to monitor them. One of the pharmacy staff stated that:

> *'We collected a large amount of data, but we never used it to understand how our process was performing'. (Field notes)*

Since sample size varied, the proportions of incorrect entry of medication orders and incorrect medication selection were plotted on a P-chart for a twenty-five-month period from December 2016 - December 2018. The data set includes counts of the length of stay (subgroup sizes) and the number of incorrect entry of medication orders and incorrect medication selection that occurred in each month. Figures 5.6 and 5.7 show that the process was out of control because most of the data points fell more than 3σ from the centre line. The average proportion of incorrect entry of medication orders and incorrect medication selection were 0.02 and 0.04 respectively (Figures 5.6 and 5.7). This was considered as the baseline data for the study (Gijo *et al*., 2013).

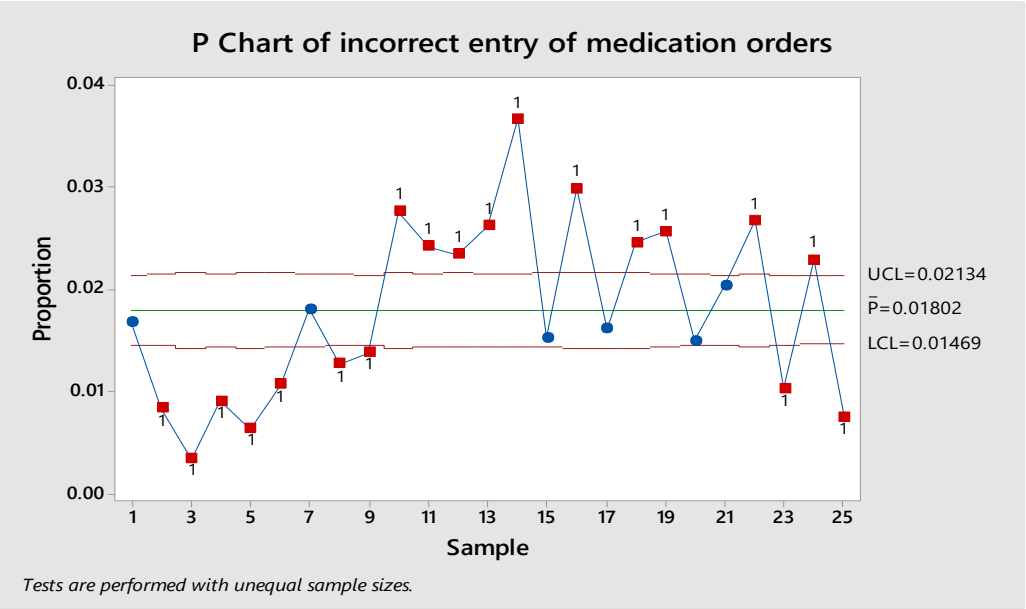


Figure 5.6 P-chart of proportion of incorrect entry of medication orders per month

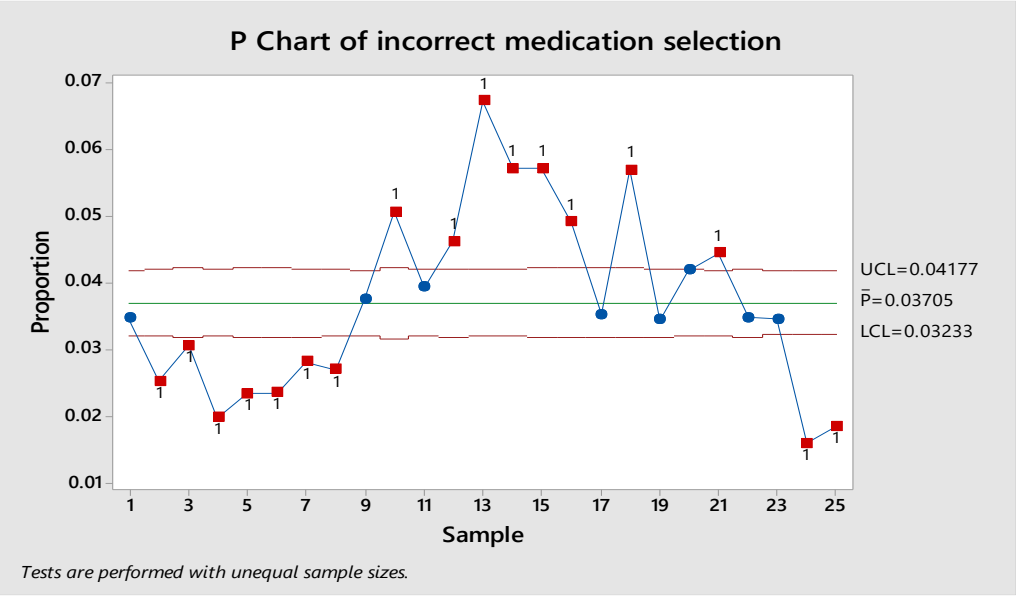


Figure 5.7 P-chart of proportion of incorrect medication selection per month

For output measure, dispensing errors detected by the nurses had been reported in the hospital risk management system (HRMS) over 25 months. After that, one of the participants manually recorded the number of undetected dispensing errors and the number of lengths of stays on an excel spreadsheet every month. Error proportions were plotted on a P-chart for a twenty-five-month period from December 2016 - December 2018. This chart showed an average proportion of undetected dispensing errors was approximately 0.002 (Figure 5.8). This was considered as the baseline performance of dispensing process. The fact that the dispensing process was out-of-control (one point falling beyond control limits and four points had a greater 1σ from the average error

proportion) highlighted a lack of strictly practiced standard operating procedures. In order to reduce process variation and improve the dispensing process performance, identifying and removing the root cause of this variation is important (Taner, 2013). The next phase will explain and identify the root causes of the problems.

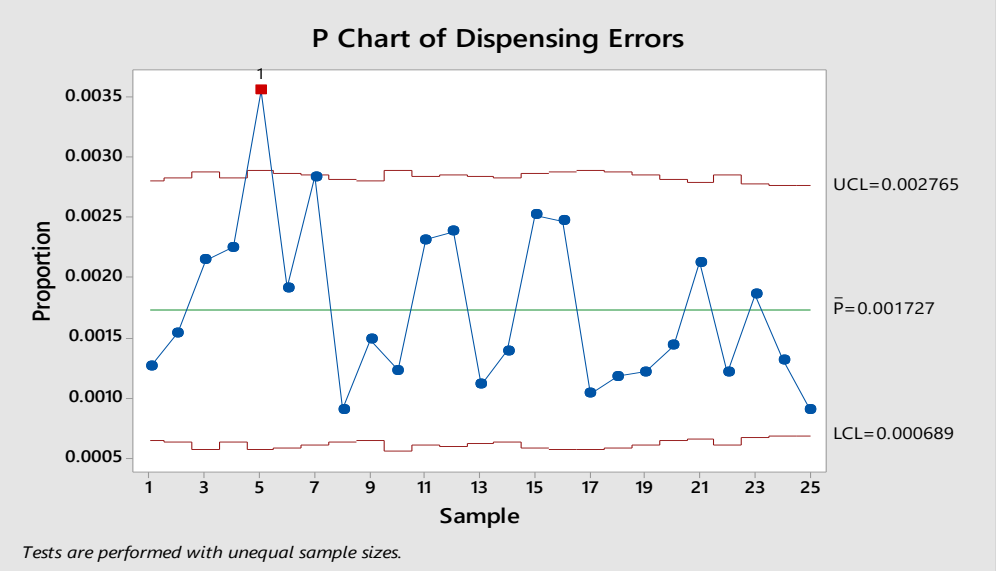


Figure 5.8 P-chart of proportion of undetected dispensing errors per month

Furthermore, errors in medication entering and medication selection were collected and visually displayed in a Pareto diagram (Elbireer *et al*., 2013). The Pareto diagram was used to compare the rate of occurrences and the type of errors in medication entering and medication selection. Figure 5.9 shows the top four 'errors in medication entering' which included patients not receiving medications, wrong route, omitted medication, and wrong quantity, accounting for 80% of all errors. The most frequent type of error in medication entering was when the patients were not receiving the medications (37 errors).

As shown in Figure 5.10, more than 80% of medication selection errors made by pharmacy technicians were associated with pharmacy technicians who forgot to 'off' medications, selected the wrong quantity, or they were omission errors (the prescribed drug did not reach the patient). The most frequent type of medication selection error was where the pharmacy technician forgot to 'off' medications (123 errors). This occurred in the medication orders, when the doctors wrote 'off' after the name of medications, meaning that these medications should not be supplied to the patient. However, the pharmacy technicians still collected and put such medications into the medication carts.

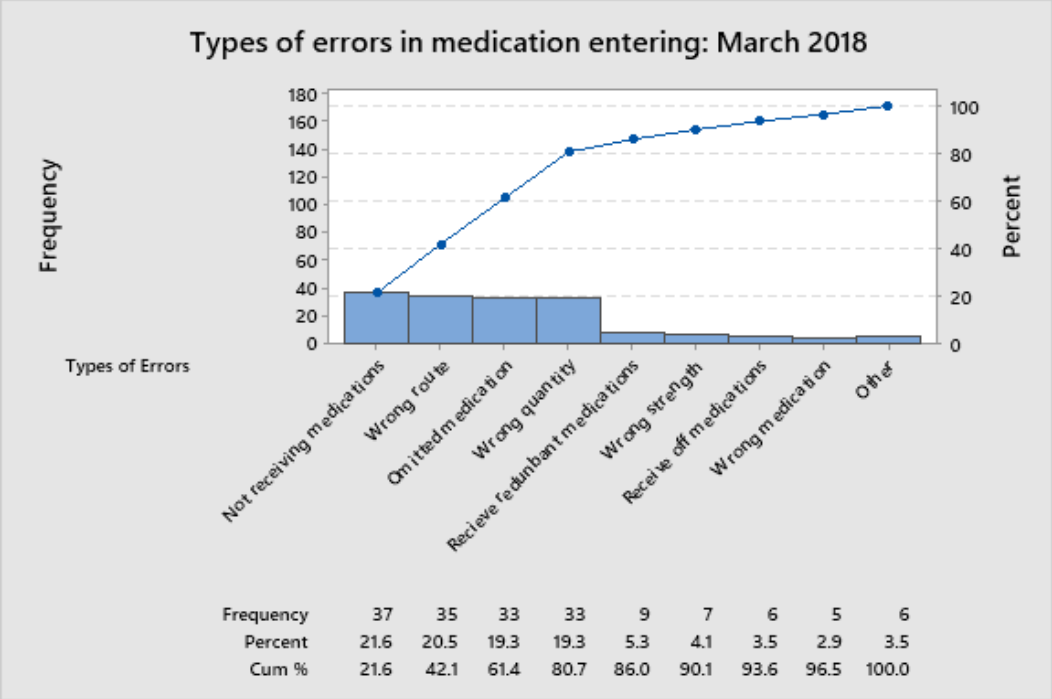


Figure 5.9 Types of errors in medication entering

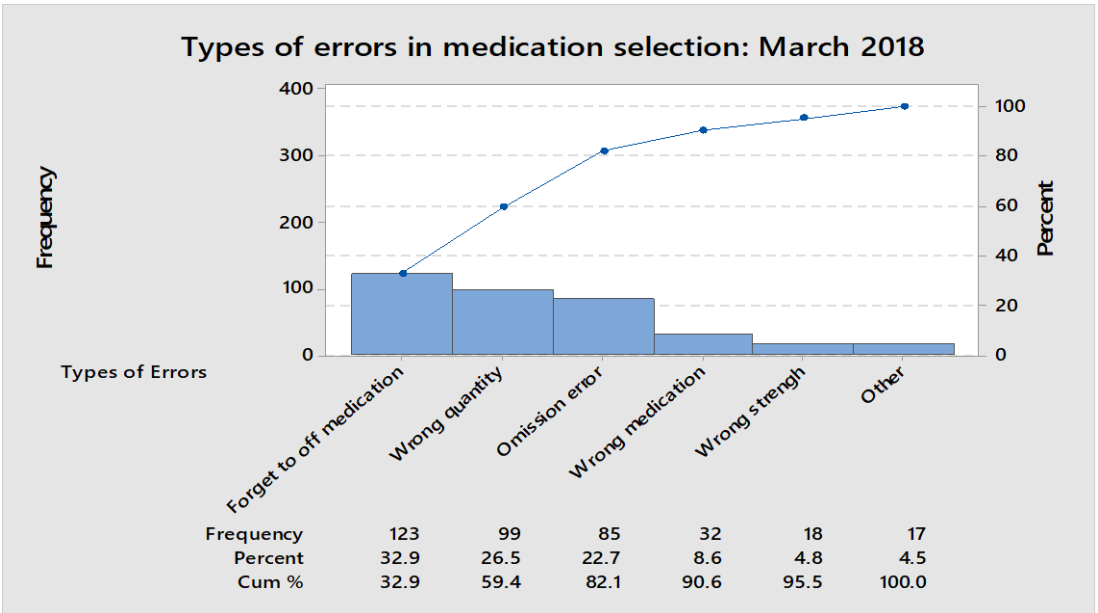


Figure 5.10 Types of errors in medication selection

3) Analyse phase

The goal of this phase was to identify the root causes of the problems. Brainstorming took place to identify the potential causes of the problems because it is a simple and useful technique to gather ideas from the participants. First, the potential causes of incorrect medication order entry and incorrect medication selection were brainstormed, and visually portrayed these using cause and effect diagrams. Afterwards, multi-voting

prioritized the three most prevalent causes. Multi-voting procedure includes the following steps (ASQ, 2019)

1. Display the list and number of all the potential causes
2. Decide how many potential causes must be on the final list and how many choices each team member can vote for.
3. Each team member selects the potential causes based on the number of choices they are allowed to vote for, then ranks the choices in order of priority, with the first choice ranking highest.
4. Record the votes by writing all of the individual rankings next to each choice.
5. Make the decision if the team members are in agreement. The team may further discuss if there is a dramatic difference in the voting.

Problem 1: Incorrect entry of medication orders

Figure 5.11 shows the potential causes of the incorrect entry of medication orders based on a cause and effect analysis. These included misinterpretation of handwritten medication orders; too rushed; computer not functioning properly; interruptions; noise and miscommunication between pharmacists and nurses. The next section explains the details of each potential cause.

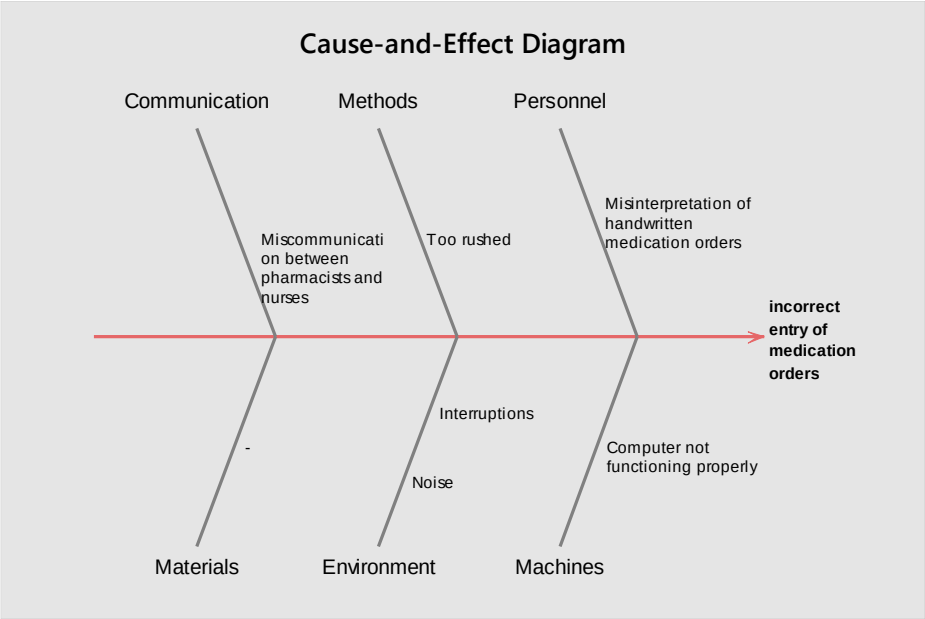


Figure 5.11 Cause and effect diagram of incorrect entry of medication orders

Personnel

- Misinterpretation of handwritten medication orders

Medication orders were written in self-copying order forms. It was difficult for the pharmacists to read unclear handwritten medication orders. The doctors' use of abbreviations, incomplete or unclear directions, and use of nonstandard nomenclature when they wrote the medication orders resulted in the mistakes. If pharmacists could not accurately read and clarify the medication orders, this could contribute to the risk of dispensing errors (Winslow and Nestor, 1997). The participants explained the reasons why they entered medication orders incorrectly:

> *'Medication orders were vague which made it difficult to read the written medication orders'. (Field notes)*

> *'Sometimes, it was difficult to read the doctor's handwriting because it was unclear'. (Field notes)*

One of the participants also mentioned about incomplete medication orders that could contribute to incorrectly entered medication orders:

> *'Sometimes, medication orders were incomplete, the patient's name was missing. I made the incorrect assumption when I could not read doctor's handwriting'. (Field notes)*

Moreover, incomplete and illegible handwriting on medication orders contributes to wasted time for pharmacists when they have to contact nurses or doctors to clarify the orders.

Method

- Too rushed

A high number of medication orders from 12 wards were sent to the inpatient pharmacy along with the medication carts. Four pharmacists hurriedly entered medication orders so that they could deliver medication carts in a timely manner. The medication order entry steps included choosing the name of medications from the hospital database system, identifying the administration schedule, medication quantity, medication route and enter any special instructions. Pharmacists were faced with limited time to enter the medication order into the patient's profile. As one of the participants said:

'When we receive a high number of medication errors, we feel too much pressure and were rushing to enter medication orders'. (Field notes)

Machine

- Computer not functioning properly

Information about an incorrect medication administration had not been removed from the system. When pharmacists printed medication labels, the incorrect medication information was also included on the label.

Environment

- Interruptions

While pharmacists were entering medication orders, there were more medication orders sent to the pharmacists. Medication orders were sent to the inpatient pharmacy after medication carts had been delivered to wards. Pharmacists lose their concentration and stop their tasks leading to the risk of medication orders entered incorrectly. Moreover, interruptions could increase pharmacists' stress and irritability. I observed another example of interruptions:

'I (the researcher) observed that pharmacy technicians were approaching the pharmacist while they were entering medication orders. The pharmacists stopped entering medication orders and responded to pharmacy technicians'. (Field notes)

- Noise

Noise can interfere with effective work performance of staff in the pharmacy technician service (Grissinger, 2012), and this can create distractions, affect concentration and it causes annoyance (Henriksen *et al*., 2005). Main sources of noise were loud music, staff talking about their personal life and resolution of medication orders issue. The high level of noise can increase the stress and fatigue of pharmacists and pharmacy technicians. One of the pharmacy technicians explained her feelings when working in this environment:

'I cannot concentrate on my job (collecting medications from the shelves). It was too noisy'. (Field notes)

'I (the researcher) was surprised when I entered the inpatient pharmacy; noise levels were so high. How can they work in this excessively noisy environment?'. (Field notes)

Communication

- Miscommunication between pharmacists and nurses

When the pharmacists received unclear written medication orders, they had to contact the nurse to clarify such orders. Sometimes, the nurse provided incorrect information to the pharmacists. The pharmacists then made errors when entering medication orders.

Furthermore, the team listed all the potential causes of the problem in order to prioritize the top three causes by using multi-voting tool. Table 5.6 shows the leading causes of incorrect medication order entry were: being too rushed, interruptions from more medication orders from the wards, and misinterpretation of handwritten medication orders.

Table 5. 6 The top three causes of incorrect medication order entry

Causes	Total Score	Ranking
1. Misinterpretation of handwritten medication orders	1+1+3+3+1= 9	3
2. Too rushed	3+2+2+2+2+2 = 13	1
3. Interruptions	2+3+3+1+3 = 12	2
4. Noise	1	4
5. Computer not functioning properly	1	4
6. Miscommunication between pharmacists and nurses	0	6

The team further used 5 why analysis as shown in Table 5.7 to drill into the root causes of the leading potential sources of each problem (van de Plas *et al*., 2017). It aims to uncover the root cause of specific problems by encouraging participants to generate their ideas based on their experience. The Head of Inpatient Pharmacy served as team facilitator, asking pharmacists and pharmacy technicians why problems occurred, recording all responses, and repeatedly asked "why" until participating pharmacists and pharmacy technicians agreed that root causes had been identified. The root causes of incorrect entry of medication orders included lack of STAT medication delivery guidelines, lack of criteria for sending medication orders to the inpatient pharmacy and

nurses not checking the legibility and not clarifying medication orders before sending these orders to the inpatient pharmacy.

Table 5.7 5 Why analysis identifying the root cause of medication orders entered incorrectly

Causes of medication order entered incorrectly	1st Why	2nd Why	3rd Why	4th Why	5th Why
1. Too rushed	Pharmacists received a high number of medication orders from wards	Lack of screening medication orders to identify whether the medication orders should be immediately sent to the inpatient pharmacy or not.	Lack of STAT medication delivery guidelines (STAT is "an abbreviation of the Latin word statim, meaning immediately without delay" Abdelaziz *et al.*(2016))		
2. Interruptions	There were more medication orders from the wards after the medication cards had been dispensed to the different wards.	Nurse did not collect medication orders and sent in different round after doctor's ward round.	Lack of criteria for sending medication orders to the inpatient pharmacy		
3. Misinterpretation of handwritten prescription orders	Illegible handwriting of doctors	Copy of medication orders are unclear (indistinct carbon copies of medication orders)	Nurses not checking the legibility and not clarifying medication orders before sending these orders to the inpatient pharmacy		

Problem 2: Incorrect selection of medications

Figure 5.12 shows the potential causes of incorrect medication selection based on findings from the cause and effect analysis. These included; talking while performing, lack of knowledge and experience, inadequate drug storage, noise, interruptions, non-compliance with medication selection standard procedures, and too rushed. The next section explains each of which potential causes.

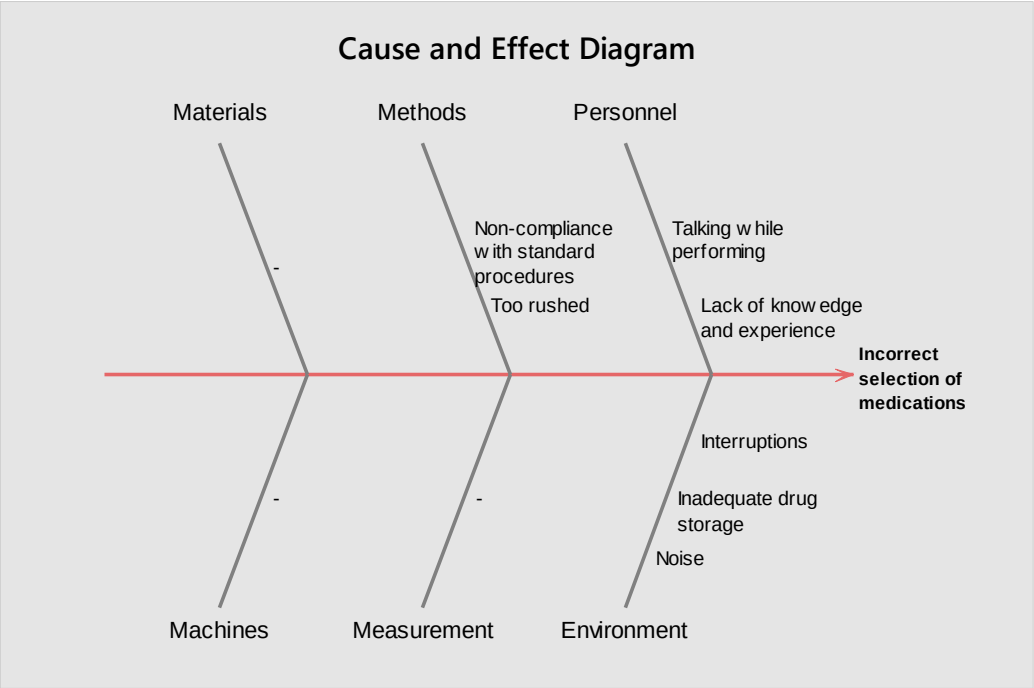


Figure 5.12 Cause and effect diagram of incorrect medication selection

Personnel

- Talking while performing

The pharmacy technicians were talking as they collected medications from the shelves and as they filled medications. Due to the layout and limited space, two participants sat opposite each other when they performed their work. This provided an opportunity for pharmacy technicians to talk excessively when collecting and filling medications. They mostly talked about their personal life. Moreover, when the pharmacy technicians were talking loudly, this could disrupt other staff, preventing them from focusing on their work, and thereby increasing the potential risk of errors. One of the pharmacists stated:

> *'Pharmacy technicians talk all the time when they perform their tasks. So, they cannot concentrate when they select medications from the shelves. This could lead to errors'. (Field notes)*

- Lack of knowledge and experience

Most of the pharmacy technicians did not possess a degree related to their jobs as pharmacy technicians. Only four pharmacy technicians had a Diploma in Technical Pharmacy. The pharmacy technicians who did not have a degree in Technical Pharmacy lacked knowledge regarding the medications being prepared. They also had no work-based experience and training in these areas. The pharmacy technicians were only supervised by pharmacists to learn how to collect medications when they started working in the inpatient pharmacy.

Environment

- Inadequate drug storage

Storage aims to keep medicines in a good condition in terms of light, temperature, and moisture throughout the drug supply cycle (WHO, 2003). All of the daily dose containers were stored in alphabetical order on shelves. However, daily dose medication storage containers were very small, and some containers contained two or three medications as shown in Figures 5.13 and 5.14. This could increase the risk of selecting the wrong medication. One of the participants said:

> *'When I collected medications from the storage boxes, if some boxes contained more than one medication, I picked another medication instead of the one that I intended to collect'. (Field notes)*

- Noise

As mentioned previously, there was a high level of noise in the inpatient pharmacy. The excessive noise interfered with the performance of staff when they were undertaking their tasks, leading to omissions and mistakes.

Figure 5.13 Daily dose storage bins and containers **Figure 5.14** Storage containers containing more than one medication

- Interruptions

There were more medication orders from the wards after the medication cards had been delivered to wards. This interruption made participants lose concentration, leading to incorrect medication selection (Binobaid *et al*., 2016) and increased risk of errors. When more medication orders were sent to the pharmacy technicians, they completely stopped their work and started collecting medications relating to such orders.

Methods

- Non-compliance with medication selection standard procedures

Pharmacy technicians collected the medications against the medication label instead of the medication order written by doctors. They were noncompliant with standard procedures for reading medication orders and medication selection. There was a standard medication preparation procedure, but it was not followed by everyone. One of the participants said:

> *'If pharmacy technicians do not follow the medication selection standard procedures when they collect medications, the errors can pass to me. If I did not check the medications carefully, these errors would not be detected and finally they reach the inpatients'. (Field notes)*

- Too rushed

Medication carts are collected by ward staff no later than 11 am and 3 pm. Collection and filling of medications must be done before the medication cart collection time. Pharmacy technicians were rushing to complete their tasks to deliver the medication cart in a timely manner. In the pharmacy service, five pharmacy technicians had to prepare medications for 24 medication carts (12 medication carts were delivered that day and another 12 medication carts were delivered the next day). For example, Figure 5.15 shows the process steps of collecting and filling medications by one pharmacy technician who responded to prepare four medication cards daily. Pharmacy technicians were not only preparing and filling medications, they also had other tasks to complete during a day such as pre-packing medications and collecting medications from ward stocks. Staff mentioned that incorrect medication selection occurred due to rushing to complete their tasks.

> *'When pharmacy technicians collected medications from shelves, they were rushing because each pharmacy technician collected approximately 1200 medication items from shelves and filled medication carts daily'. (Field notes)*

> *'Pharmacy technicians thought that the errors occurred because they lacked time to prepare and fill medication. Also, they thought that medication carts would be checked by the pharmacist again'. (Field notes)*

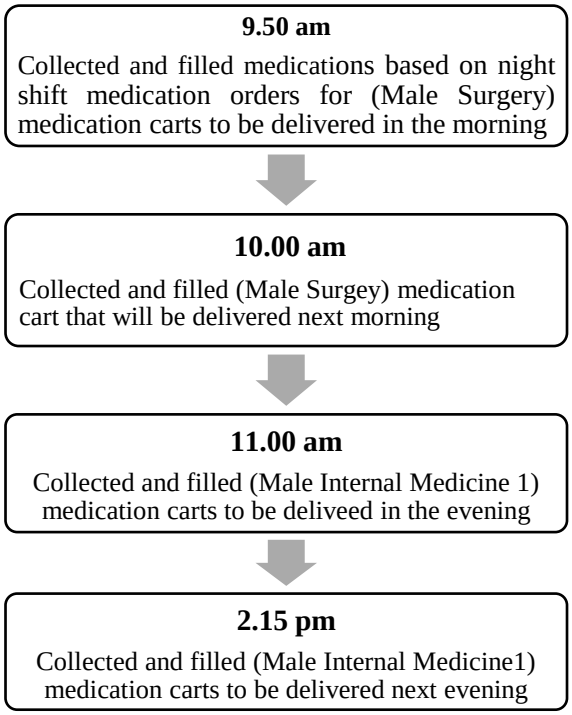


Figure 5.15 Daily dose medication selection and filling process

Using multi-voting tool, the identified potential causes were further prioritized into the three most prevalent causes. Table 5.8 shows the leading causes of incorrect medication selection were: being too rushed, non-compliance with standard medication selection procedures, and interruptions from more medication orders. The team further used 5 Why analysis to identify the root causes of the leading potential causes of incorrect medication selection, as shown in Table 5.9. The root causes of incorrect medication selection were: daily dose medication preparation was complex and lack of criteria for sending medication orders to the inpatient pharmacy respectively.

Table 5.8 The top three causes of incorrect medication selection

Causes	Total Score	Ranking
1. Too rushed	3+2+2+3+2+3= 15	1
2. Non-compliance with standard medication selection procedures	1+3+3+2+1+2= 12	2
3. Interruptions	2+1+1+1+3= 8	3
4. Talking while performing	0	4
5. Lack of knowledge and experience	0	4
6. Inadequate drug storage	0	4
7. Noise	0	4

Table 5.9 5 Why analysis identifying the root cause of incorrect medication selection

Causes of incorrect medication selection	1st Why	2nd Why	3rd Why	4th Why	5th Why
1.Too rushed	Staff had to perform many steps to complete their tasks.	Daily dose medication preparation was complex.			
2.Non-compliance with the medication selection standard procedures (Pharmacy technicians did not collect medications based on medication orders)	Too rushed	Staff had to perform many steps to complete their tasks.	Daily dose medication preparation was complex.		

3. Interruptions	There were more medication orders from the wards after the unit cards were delivered to the different wards.	Nurse did not collect medication orders and sent in different round after the doctors' ward rounds.	Lack of criteria for sending medication orders to the inpatient pharmacy

4) Improve Phase

The aim of this phase is to develop and implement the potential solutions that can address the root causes of the problem. Once the root causes were understood, multiple brainstorming sessions were conducted to generate potential solutions (Elbireer *et al*., 2013). They then implemented the most appropriate solutions and observed the results (Gijo *et al*., 2018). Table 5.10 presents the potential solutions identified to minimize root cause effects. The project team agreed that these chosen solutions were the most effective to solve the problems with the least cost and most ease of implementation. Following this, the project team prepared the plan for implementing these solutions and assigned responsibilities and target completion dates, with implementation occurring over two months as shown in Table 5.11.

Table 5.10 Potential solutions to minimize each selected root cause

Potential causes of incorrect entry of medication orders	Root causes	Potential solutions	Follow-up plan
1. Too rushed	Lack of STAT medication delivery guidelines	Develop a guideline for STAT medications ordering process	The Head of Inpatient Pharmacy arranges a meeting with pharmacists to ensure that nurses and doctors follow a guideline for ordering STAT medications.
2. Interruptions	Lack of criteria for sending medications orders to the inpatient pharmacy	Develop criteria for nurses to deliver medication orders	The head of each ward regularly checks to ensure that nurses follow the criteria.
3. Misinterpretation of handwritten prescription orders	Nurses not clarifying medication orders before sending these orders to the pharmacy service	Develop a standard practice for nurses to follow before sending medication orders to the inpatient pharmacy	The head of nursing regularly checks to ensure that nurses follow the criteria.

Potential causes of incorrect medication selection	Root causes	Potential solutions	Follow–up plan
1. Too rushed	Daily dose medication preparation was complex	Re-design the process of daily dose medication preparation	The Head of Inpatient Pharmacy checks every week to ensure the staff have followed the new procedures.
2. Non-compliance with the medication selection procedure	Daily dose medication preparation was complex	Re-design the process of daily dose medication preparation.	The Head of Inpatient Pharmacy checks every week to ensure the staff have followed the new procedures.
3. Interruptions	Lack of criteria for sending medications orders to the inpatient pharmacy	Develop criteria for nurses to deliver medication orders	The head of each ward regularly checks to ensure that nurses follow the criteria.

Table 5.11 Implementation plan for each selected root causes

Implementation Plan		
Action items	**Persons responsible**	**Due date**
Review and develop a guideline to be followed by nurses and doctors for ordering STAT medications	The Head of Inpatient pharmacy and Pharmacists	30 Oct 2018
Develop criteria for nurse to deliver medication orders	Pharmacists	30 Oct 2018
Develop a standard practice for nurses to follow before medication orders are sent to the inpatient pharmacy	The Head of Inpatient Pharmacy	30 Oct 2018
Re-design the process of daily dose medication preparation	Action research team	30 Oct 2018

The followings are the explanation of each potential solution identified in Table 5.10

- **Develop a STAT medications ordering process guideline**

Misunderstanding between practitioners involved in STAT medication administration and dispensing resulted in some patients not receiving their medication on time, thereby elevating their risks. Since a high number of medication orders were sent to the pharmacists, the team met with the Pharmaceutical and Therapeutic Committee (PTC) to review and develop a STAT medications ordering guideline for nurses and doctors to follow. The following are the details of the STAT medications ordering process guidelines:

1. List of medications for STAT administration and dispensing
2. STAT administration time
    2.1 Order for one day- medication orders written as STAT should be administered to the patient within 30 minutes of the time that the order is written by doctors (Atanelov, 2016).
    2.2 Order for continuous - medication orders written as STAT should be administered to the patient within 60 minutes of the time that the order is written by doctors (Atanelov, 2016).
3. Doctors should indicate in the medication orders when medications need to be STAT.
4. In the case of doctors ordering STAT medication or medication within STAT administration
    4.1 If there are medications in ward stock, nurse could directly give medication to patient.
    4.2 If there are no medications in ward stock, nurse should send medication orders and write in medication orders as STAT.

- **Develop criteria for nurses to deliver medication orders**

The pharmacists asked for cooperation of ward nurses from 12 wards to collect all medication orders after doctors' morning and afternoon ward rounds (10 am and 2 pm). The inpatient pharmacy staff would then collect the medication orders for the different wards.

- **Develop standard practices for nurse to follow before sending medication orders to the inpatient pharmacy**

The team decided to develop standard practices for nurses to follow before sending medication to the inpatient pharmacy, so that whenever a nurse encounters unclear, incomplete and/or inappropriate medication order (e.g. due to illegible handwriting), they have to confirm the medication orders with the doctor who wrote the original medication order. After verification, the nurse corrects the medication orders details before sending them to the pharmacists.

- **Redesign the daily dose medication preparation process**

The project team decided to redesign the existing daily dose medication preparation process. All medication carts for all 12 wards were prepared on a day-by-day basis, with pharmacy technicians no longer needing advance preparation of medication carts. The

new process began with pharmacists entering medication orders from the night shift during night time. In the morning, the pharmacist could print the medication labels for pharmacy technicians to prepare medications. Pharmacy technicians were classified into two main groups. The first group was responsible for the preparation of medication based on the night shift orders and a batch of repeat medication orders. Another group was preparing medications based on medication orders from the morning round and afternoon round. If medication orders had changed, these pharmacy technicians responded to change the medication that had already been prepared by the first group.

As mentioned previously, all medication filling and cross-checking by pharmacists must be done before the medication carts' collection time. All of the participants were anxious if pharmacy technicians had not prepared medication cards in advance, the medication carts could not be delivered on time. Therefore, this solution was first piloted with four wards for one month: ICU; Chronic Respiratory Care Unit; Female Surgery and Male Internal Medicine 3. After piloting, pharmacy technicians provided a positive feedback on the improvement.

> *'I am very satisfied with the new daily dose medication preparation process. I did not need to change medications that I already prepared such as off medications'. (Field notes)*

> *'The return of unused medications was dramatically reduced. It was saving my time to put unused medication back on to the shelves'. (Field notes)*

The participant further decided to implement these solutions on all of 12 wards. Figure 5.16 shows the process steps of the new daily dose medication preparation. Three pharmacy technicians selected and filled medication for 12 wards regarding the night shift medication orders and a batch of repeat medication orders (each pharmacy technician was attached to four wards). Another two pharmacy technicians prepared medication if there were any changes with the prepared medication carts based on the medication orders from the morning and afternoon round times (each pharmacy technician was attached to six wards).

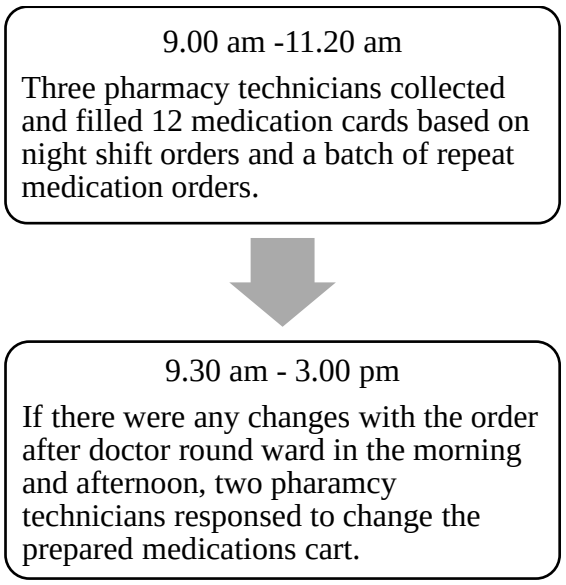


Figure 5.16 The process steps of new daily dose medication preparation process

Additionally, staff could not recognize the difference between prepared, checked and ready to deliver medication carts. Figure 5.17 shows three different coloured signs were designed to differentiate medication carts. Blue, yellow and green represented prepared, already checked by pharmacists and ready to deliver medication carts, respectively. The sign was placed on top of the medication carts to show the status of such carts, as illustrated in Figure 5.18.

Figure 5.17 Coloured sign to distinguish medication cart

Figure 5.18 The green sign represented the medication cart that was to be delivered

4) Control Phase

The goal of this phase was to sustain the improved process that has been achieved from the improve phase so that the following mechanisms were implemented.

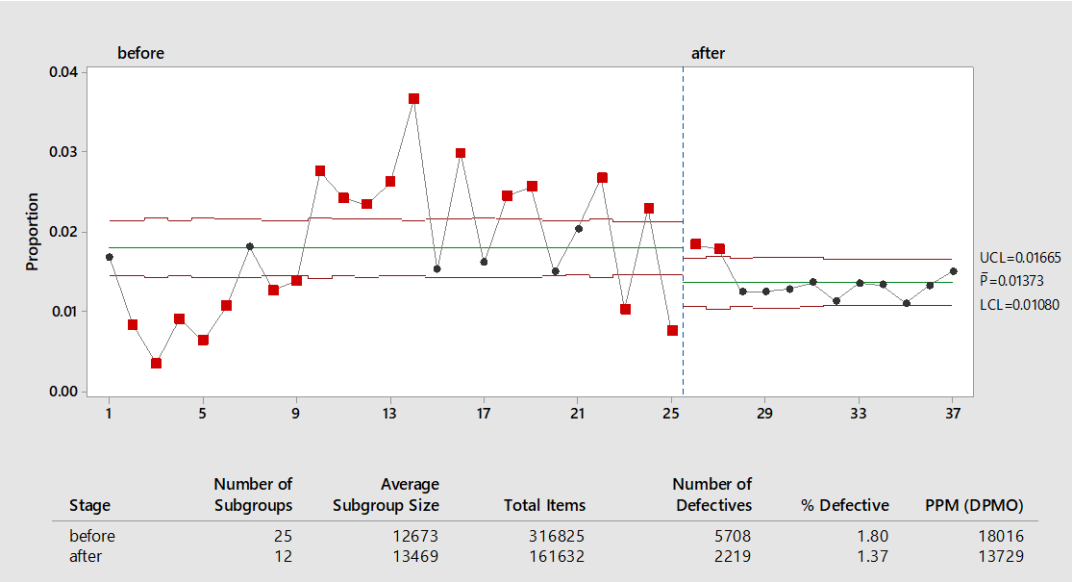
- Standard operating procedures (SOPs) development:

An SOP was used in the control phase to ensure the medication selection process steps were carried out correctly and consistently (Antony *et al*., 2016). A new daily dose medication preparation procedure was standardized and placed near the pharmacy technicians' workstation. SOPs provided detailed tasks descriptions, and persons responsible. Inpatient pharmacy staff were trained to use SOPs, ensuring staff understood and correctly followed instructions. Implemented SOPs were evaluated and updated monthly. The Head of Inpatient Pharmacy regularly monitored staff to ensure SOPs were followed.

- Statistical process control implementation:

A P-chart was developed to monitor the monthly dispensing process, track trends, and detect unusual process behaviour (Taner, 2013). It helped the team to control the performance of dispensing process and can take action when any signal for an assignable cause appeared in the control chart (Bhat *et al*., 2014). The Head of Inpatient Pharmacy discussed the associate issue with the staff and took corrective actions to resolve the cause of variation (Bhat *et al*., 2014).

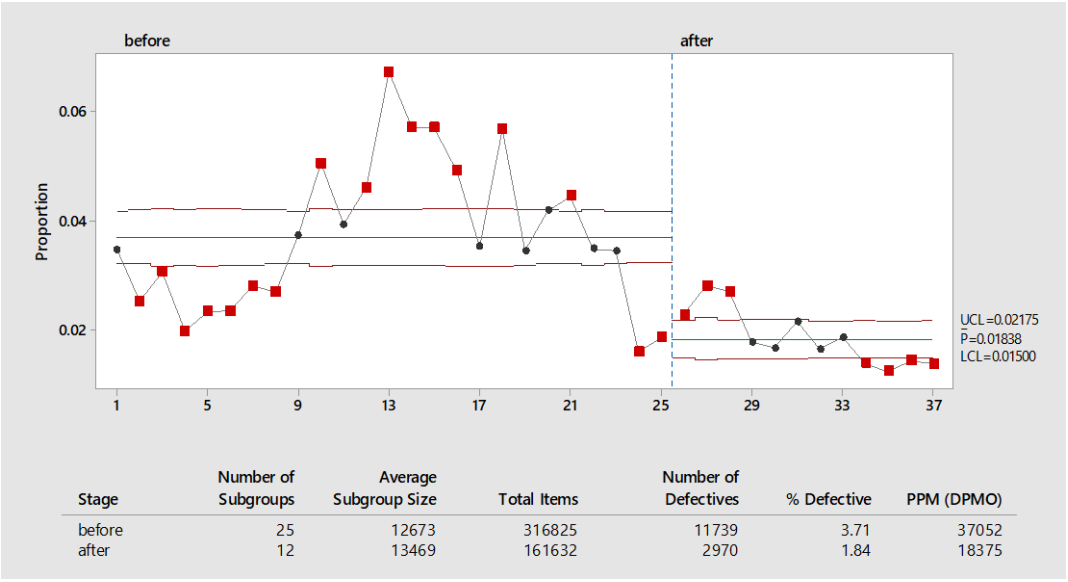
After intervention implementation, the proportion of incorrect entry of medication orders was collected and plotted on a P-chart over the next 12 months. The P-chart in Figure 5.19 compared the proportions of incorrect entry of medication orders before and after the improvements. The figure shows that the process was out of control due to the special causes within the process. The special causes resulted from miscommunication between nurses and pharmacists related to STAT medication orders. However, the average proportion of incorrect entry of medication orders was significantly reduced from 0.018 to 0.014 ($p<0.05$).



Stage	Number of Subgroups	Average Subgroup Size	Total Items	Number of Defectives	% Defective	PPM (DPMO)
before	25	12673	316825	5708	1.80	18016
after	12	13469	161632	2219	1.37	13729

Figure 5.19 P-chart of incorrect entry of medication orders before and after the improvements

The P-chart in Figure 5.20 compares the proportion of incorrect medication selection before and after the improvements. The chart shows that during the three months following the changes in the process, the new process was unstable and out of control. This might be because of a lack of staff in the inpatient pharmacy and the errors caused by newly trained staff. However, after a process change, the average proportion of incorrect medication selection was significantly reduced from 0.037 to 0.018 ($p<0.05$).



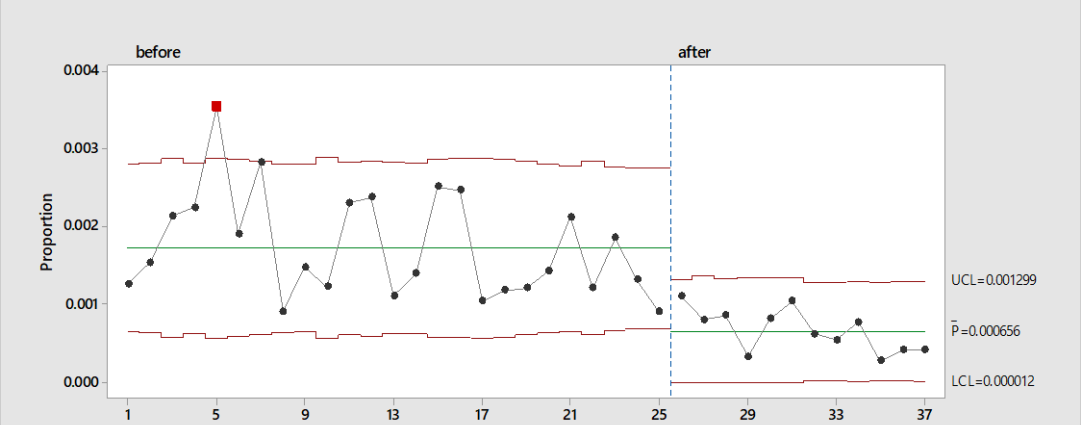
Stage	Number of Subgroups	Average Subgroup Size	Total Items	Number of Defectives	% Defective	PPM (DPMO)
before	25	12673	316825	11739	3.71	37052
after	12	13469	161632	2970	1.84	18375

Figure 5.20 P-chart of incorrect medication selection before and after the improvements

The P-chart in Figure 5.21 compares the dispensing errors' proportion before and after the improvements. The average undetected dispensing errors' proportion was reduced from 0.002 to 0.0007. The variation in the dispensing process was also considerably

reduced. The changes have had a significant impact on the proportion of dispensing errors. Moreover, the number of dispensing errors reduced from 29 errors in March 2018 to 6 errors in December 2019 per average 14,000 inpatient days per month. This represents an 80% reduction. Comparison of results before and after the study is summarised in Table 5.12.

A non-parametric statistical hypothesis test was used to compare the number of dispensing errors before and after the implementation of LSS. In this study, a Wilcoxon signed rank test was used to compare pre (Mean= 24.50, SD= 7.38) and post (Mean= 8.83, SD= 3.43) LSS implementation. Two groups (n= 12) of the number of dispensing errors before and after LSS implementation were taken with a purposive sampling for the comparison. The use of purposive sampling allows the researcher to access a particular set of data. The results indicated that following LSS implementation, the number of dispensing errors significantly decreased (Z = -2.61, p = 0.009).



Stage	Number of Subgroups	Average Subgroup Size	Total Items	Number of Defectives	% Defective	PPM (DPMO)
before	25	12671	316776	547	0.17	1727
after	12	13469	161632	106	0.07	656

Figure 5.21 P-chart of undetected dispensing errors before and after the improvements

In addition, the most frequent type of errors in medication entering was when the patients were not receiving medications and this reduced from 37 to 17 errors between March and December 2018 (Figure 5.22). The most frequent type of medication selection errors was where the pharmacy technician forgot to ‘off’ medications and this reduced from 123 to 53 errors between March and December 2018 (Figure 5.23).

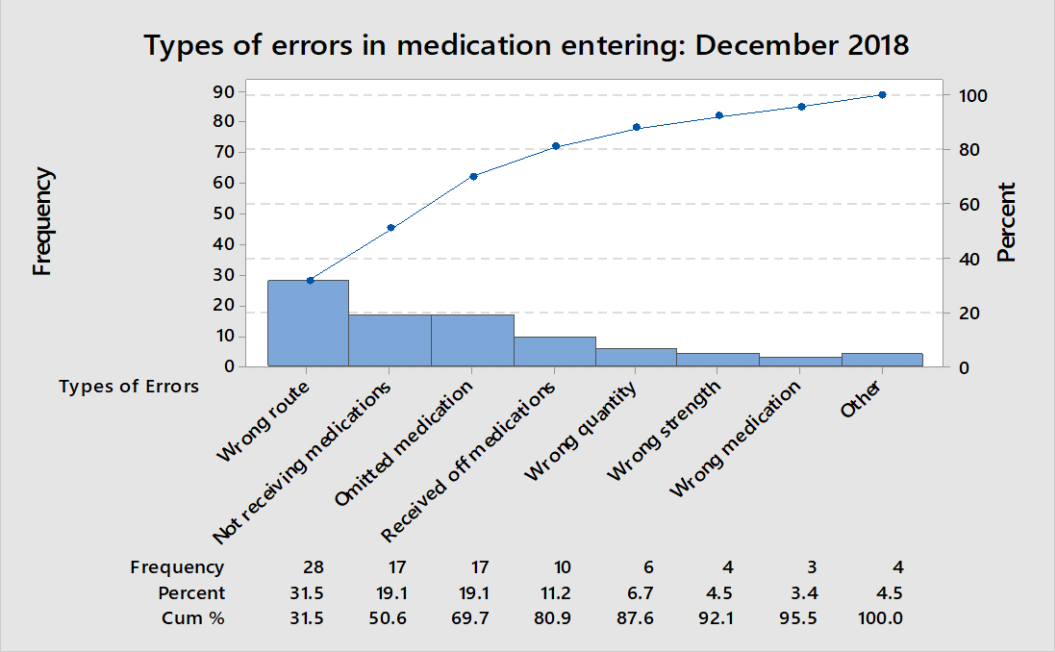


Figure 5.22 Types of errors in medication entering after the improvements

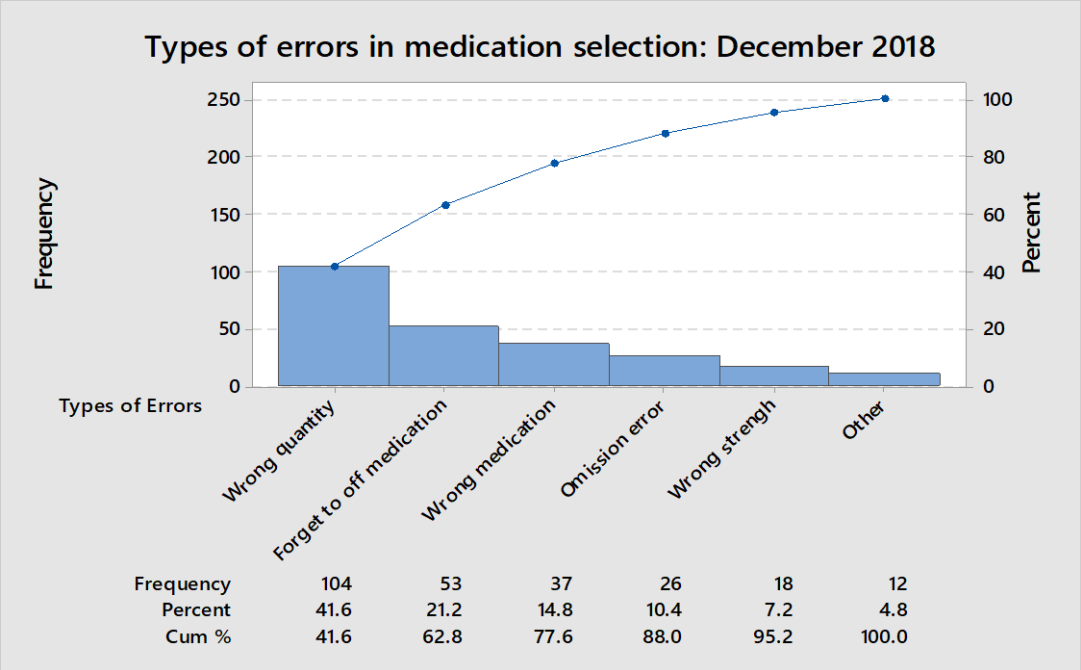


Figure 5.23 Types of errors in medication selection after the improvements

Table 5.12 Comparison of results before and after the study

Measurement	Before	After	Percentage reduction
Process measurement			
• Incorrect entry of medication orders	average proportion = 0.018	average proportion = 0.014	22.22
• Incorrect selection of medications	average proportion = 0.037	average proportion = 0.018	51.35
Outcome measurement			
• Dispensing errors	average proportion = 0.002, SD= 0.0083	average proportion = 0.0007, SD= 0.0074	65
Number of dispensing errors	29 errors in December 2018	6 errors in December 2019	80

Phase 5: Evaluation and Reflection

After conducting an interview with participants, five main themes emerged and are summarised in Table 5.13. The details of each theme are explained in the following sections. The challenges and success factors of LSS implementation are presented in the next section.

Table 5.13 Themes and sub-themes identified in the evaluation and reflection phase

Themes	Sub-themes
Change in dispensing process	Dispensing process flow improvement Dispensing process variation reduction
Increased in staff' morale	-
Thoughts about DMAIC methodology and its applications in the dispensing process	Problem-solving methodology Holistic view of problems Understand and evaluate the root cause of the problem LSS can be applied in the dispensing process.
Feedback from LSS training	Knowing more about LSS and its tools and techniques Appreciate Lean and Six Sigma tools and techniques
Knowledge gained from the project	The power of data

1) Change in dispensing process

Many changes in the dispensing process resulting from the implementation of LSS were perceived by the participants. The key changes included: dispensing process flow improvement and dispensing process variation reduction which are explained as follows.

A. Dispensing process flow improvement

Dispensing process flow was improved by the elimination of wastes in the dispensing process (e.g. waiting for medication orders, preparing medication cards in advance, and excessive movement of pharmacy technicians). Owing to the reduction of unnecessary process steps, the workload for many of the staff decreased, which in turn helped them to complete their tasks more easily. Participants described how their routine tasks were improved, due to the elimination of such waste:

> *'Before implementing LSS, I had to prepare and fill medication for four medication carts. I had to do many things such as prepare and fill medication, remove the prepared medication when medication orders had changed and when the patients were discharged, I had to remove all their prepared medication from four medication cards. After LSS had been implemented, the dispensing process flow was improved so that it was much easier to complete my work'. (Pharmacy technician)*

> *'I really liked the improved daily dose medication preparation process. I had been working here for six years but it never changed. You (the researcher) were an agent for this change and helped senior staff to be open-minded'. (Pharmacy technician)*

B. Dispensing process variation reduction

Implementing potential solutions to minimize the impact of the root causes of the problems resulted in variation reduction in the existing dispensing process. This contributed to a reduction in dispensing errors both detected and undetected by pharmacists. Participants stated that the number of detected dispensing errors was decreased because the pharmacy technicians were more able to concentrate on their specific tasks without distractions. Moreover, pharmacists who entered medication orders into the system could concentrate on their tasks due to a reduction in the number of

medication orders. The implementation of LSS not only improved workflow and reduced dispensing errors, but also improved staff' morale.

2) Increased in staff' morale

All participants felt that the employment of LSS improved the quality of their working life and working performance. The following described some participants' feelings:

> *'I was very happy when I worked, and I felt that my life was better than before'. (Pharmacy technician)*

> *'The thing that we experienced after LSS had been implemented was happiness when working'. (Pharmacy technician)*

> *'I was very satisfied with the new system. It decreased the workload; however, it took a bit time to adjust to the new system'. (Pharmacist, Field notes)*

Two pharmacy technicians who were not team members further expressed their views about the new daily dose medication process:

> *'We were very satisfied with the improved medication preparation process because we did not need to change the prepared medication. It also reduced the pharmacist's job because they did not need to check such a high number of medication cards'. (Field notes)*

> *'I was able to carefully collect and fill medication carts because I did not need to do my job such a hurry'. (Field notes)*

Pharmacists described their feelings about the reduction in the number of medications orders from 12 wards.

> *'We were very satisfied with the improved process. The number of medication orders from wards had decreased. I could concentrate more when I entered medication orders in the e-hospital system'. (Pharmacists)*

Participants mentioned that the pharmacy technicians had more time available to organise other assigned jobs, as explained by two pharmacists:

'Due to the elimination of non-value added activities when pharmacy technicians prepared daily dose medication, they had more time available to do other tasks such as pre-pack medications'.

The participants and staff were happier after the researcher had engaged with the project. The implementation of LSS provided the potential solutions that facilitated the staff to complete their jobs more easily and reduced their workload.

3) Thoughts about DMAIC methodology and its applications in the dispensing process

A. Problem – solving methodology

Participants discussed the impact of LSS intervention on their own practice in terms of problem-solving methodology. The application of DMAIC methodology allowed the participants to understand where the problems occurred in the dispensing process and during which process step, and identify the root causes of the problems. Participants stated:

'The structure of DMAIC methodology was clear and easy to follow'.

'DMAIC methodology helped us to understand which process step the problems laid in. So, we knew that these process steps contributed to a higher number of dispensing errors. When we eliminate the roots cause of these problems, the process is improved'.

The application of DMAIC methodology not only facilitates the understanding of the problems within the dispensing process, but also brought tools and techniques to help participants to see the bigger picture.

B. Holistic view of problems

Some participants claimed that they knew that these problems had existed in the process for a long time, but it was difficult to identify the solutions and start solving the problems. Participants benefited from DMAIC methodology, as they then understood a holistic view of problems. Two participants explained:

'I was faced with these problems, but I did not know where I should start to solve these problems. When we used a cause and effect analysis in the analyse phase, I could see the problems in more detail and gained a clearer picture'.

'Due to a clear structure of DMAIC methodology and several ideas generated by all team members, it presented me with a comprehensive view of problems'.

C. Understand and evaluate the root cause of the problems

DMAIC methodology guided participants to identify the root causes of the problems, as they normally identified causes of the problems from the outcome without considering the problems within the dispensing process. For example, this happened when the wrong medication was dispensed to the patient and this incident had been reported by nurses. The pharmacies arranged a meeting to identify the cause of the incidence and identify solutions to solve such occurrences. One of the participants explained how DMAIC methodology could help the participants to determine the root causes of the problems:

'I like the way of identifying the root causes of the problems. We never determined the root causes of the problems by starting from the problems in the process. We always began with the outcome of the problems (dispensing errors) and randomly identified causes of the problems based on our opinions which were not the real root causes of the problems. We did not follow a structure like this (DMAIC methodology)'.

D. LSS can be applied in the dispensing process

After the implementation of LSS, all participants were very convinced that LSS could be applied in the dispensing process. The primary reason that participants were not applying LSS before in the pharmacy service was that they did not know about LSS. Participants considered that DMAIC methodology was a clear structure and rigorous methodology for solving problems. However, some of the participants claimed that they had applied approaches which were similar to some phases of DMAIC methodology such as identifying the problem and its causes by using a cause and effect analysis. Participants clarified this as follows:

'Even though we may not have considered the name of LSS, some phases of DMAIC methodology were the same as what we had already used. For example, when there were dispensing errors, we used cause and effect analysis to find the cause of each case of the incidences'.

'We knew the problem, collected the data and found the cause of the problem. However, we did not connect all of these phases together like DMAIC methodology does'.

4) Feedback from LSS training and reflection on LSS tools and techniques

LSS training increased participants' awareness of LSS principles and understanding of how to implement its tools and techniques. The following sub-themes demonstrate how participants gained more knowledge regarding LSS tools and techniques.

A. Knowing more about LSS and its tools and techniques

All the participants identified that LSS training had resulted in more knowledge about LSS and its tools and techniques. They understood a clear structure of DMAIC methodology and understand the goal of common tools used in each phase of the methodology. The participants were able to choose the appropriate tools in each phase of DMAIC methodology. The following described how participants' knowledge had been improved:

'I never heard this term before. I obtained more knowledge on LSS methodology'.

'I understand more about tools and techniques of LSS; we could further use these tools and techniques to eliminate waste and improve the processes'.

'We knew what the problems were, but we did not know of any tools to solve these problems. Now, we could apply LSS tools and techniques that we had learnt to solve the problems'.

B. Appreciate Lean and Six Sigma tools and techniques

The participants who were pharmacy technicians felt that cause and effect analysis and spaghetti diagrams were very useful. They could understand the causes of the problems in more detail and gain a clearer picture. In addition, the spaghetti diagram helped them to see the redundancy in the distances travelled between their workspace and the front counter. The participants had encountered these problems, but visual presentation tools provided an overall picture of the problems. However, pharmacists identified that the control chart was most beneficial, particularly for top management in the hospital. They could use the control chart to monitor the process of change over a period of time.

5) Knowledge gained from the project (feedback of participants' knowledge)

'The power of data'emerged as a key aspect that participants gained from the employment of the LSS project. They considered that the data obtained enabled them to present the problem to top management.

A. The power of data

Participants felt that the analysis of data within LSS methodology was powerful. Participants (all pharmacists) reported that they had a great deal of data available, but they had never analysed it or used it for problem-solving. Participants realised that it was important to use data to make decisions in each phase of DMAIC methodology. One of the participants described the use of data analysis:

> *'The top management of the hospital could not understand the problems when we presented data to them because of ineffective data presentation. Now, we could analyse the data and show them so they can understand more about the problems, and they could support us to do other incoming projects'.*

One of the participants further supported this point:

> *'We did not know which data we should present to the top management. Our presentation made them think that what we presented were not problems'.*

The next section moves on to present the survey results to measure satisfaction of inpatients with the quality of inpatient pharmacy services before and after the implementation of LSS. The survey results are presented in two parts: sample characteristics and overall inpatient satisfaction.

- **Inpatient satisfaction**

A. Sample characteristics

Of the 30 respondents, most participants were female (60 per cent). Approximately one-third of participants were 55-65 years old and from a female surgery ward. In terms of educational background, over half of the participants (56.7 per cent) had primary school education. The majority of the respondents stayed in the hospital from one to three days and their health status was described as 'fair'.

B. Overall inpatient satisfaction

Table 5.14 showed that patient satisfaction with the quality of pharmacy services after LSS implementation (Mean= 4.38, SD= 0.56) was higher than before LSS implementation (Mean= 4.00, SD= 0.45). These results indicate that there was a statistically significant increase in overall inpatient satisfaction ($p < 0.05$). Focusing on receiving wrong medications, none of the participants said that they had received incorrect medications. It is important to mention, however, that patients characteristically do not know what the medication is when nurses administer it to them; therefore, they are unable to judge the medications they receive.

Table 5.14 Overall inpatient satisfaction

	Mean	N	SD
Before intervention	4.00	30	0.56
After intervention	4.38	30	0.45

Phase 6: Specifying lessons learnt

Two themes emerged from the lessons learnt from the project. These included increased awareness of problem-solving tools and transforming a culture to continuous improvement.

1) Increased awareness of problem-solving tools

A. Brainstorming

Brainstorming was a powerful tool identified by participants. The ideas generated by everyone involved in the dispensing process during the brainstorming session were valuable for solving the problems. The following participants described these aspects:

> *'We (pharmacists) never used to engage pharmacy technicians in the brainstorming session. When we wanted to generate ideas for solving problems, we only did this by ourselves. In this project, pharmacy technicians were involved in the team, and we could accept their perspectives and limitations. If pharmacy technicians generate the solutions themselves, it is better for them instead of working from our orders'.*

'Pharmacy technicians became a part of the team and they could offer several solutions. This is a strong point' (Field notes)

'No matter what, if we (pharmacists and pharmacy technicians) cooperate and discuss together we definitely can solve the problems. It is better now than when we ignored the problems and these problems could lead to patient dissatisfaction'.

2) Transform a culture to continuous improvement

Participants felt that this project provided an opportunity for frontline staff to be more adaptable towards other approaches to improve their work. Open-mindedness in staff facilitated the implementation of LSS in other areas in the inpatient pharmacy and other departments in the hospital. One of the participations suggested:

'We had learnt from this project that we could continually use LSS to resolve the problems that had not been resolved yet. The process would be continually improved'.

Another participant further expanded:

'The LSS project could facilitate the pharmacy technicians to create the ideas to improve their own practices'.

The introduction of LSS can change the culture to achieve continuous improvement in the pharmacy service, once the frontline staff buy-into and perceive the benefits of LSS.

5.2.2 Lean methodology in three days dose distribution system

The following section presents the findings from Lean methodology to reduce patients' relatives waiting time to receive medication in the inpatient pharmacy.

- ***Problem statement***

The longer waiting time was the main issue in the eyes of patients' relatives and pharmacists. The waiting time for patients' relatives to receive the medication was as high as 60-90 minutes. This longer waiting time resulted in delays in patient treatment (Gijo and Antony, 2014). Value stream mapping (VSM) was used to improve the flow of three-day doses dispensing process. The next section explains the application of VSM.

- ***Value Stream Mapping***

VSM was used to identify the problems and non-value added activities within the three day doses dispensing process, which had contributed to patients' relatives dissatisfaction. Figure 5.24 shows that the process began with pharmacy technicians receiving and entering medication orders into the system, and printing medication orders on labels. Afterwards, the pharmacist checked the medication labels against medication orders. After the medication labels were approved by the pharmacist, pharmacy technicians further prepared medications and these medications were screened by another pharmacy technician. Finally, front staff pharmacists checked and dispensed medications to patients' relatives.

After analysing the current state of the three day doses dispensing process, the problems and wastes were identified as follows.

- Bottlenecks

  A high number of prepared medications were waiting to be dispensed by pharmacists. As a result, there was a long waiting time (20 minutes) between the last two stages which were screening the prepared medications and checking and dispensing such medications.
- There was an uneven workload during the day, particularly between 10 am-12 pm and 2-4 pm, as the number of patients and patients' relatives peaked at those times. Although the pharmacy service started at 8.30, the patients' relatives tended to come during the busy periods and therefore had to wait a long time.
- The screening of prepared medications by another pharmacy technician was a non-value added step because it was an unnecessary inspection. Even though the pharmacy technicians checked the prepared medication, there were still some errors detected by pharmacists.

Figure 5.24 shows that the total lead time and total process time was 41.56 and 14.27 minutes, respectively. In order to understand the variation in total lead time as well as processing time, a histogram was developed to show the distribution of lead time and processing time

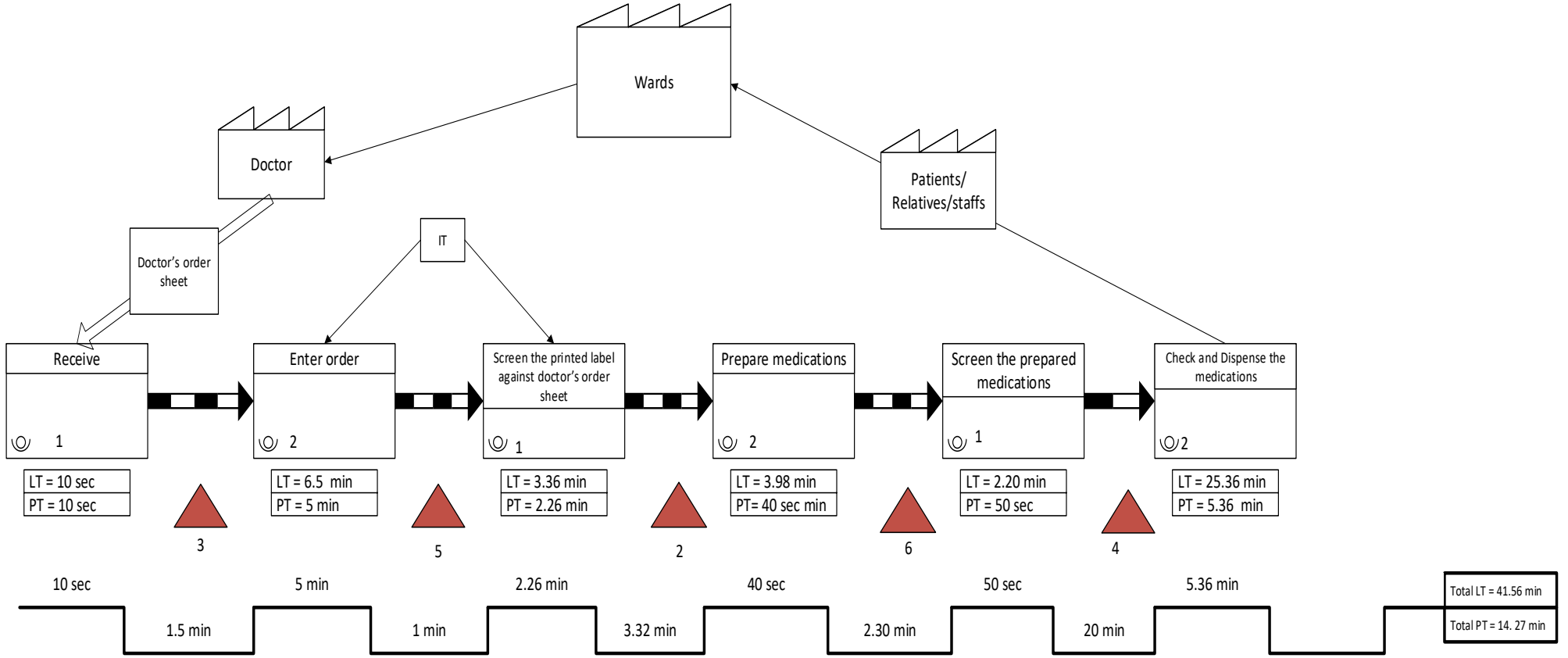


Figure 5.24 Current state of three days dose dispensing process

Figures 5.25 and 5.26 indicate that the histogram of process time and lead time showed a systematic shape, with the process centred around the mean of 8.81 and 23.68 minutes and the standard deviation was 5.49 and 10.75 minutes. After the current state map was constructed, the team decided to implement the following solutions to reduce the problems revealed by the current state of VSM.

- Eliminate non-value-added steps

  The team decided to eliminate the screening of prepared medication by the pharmacy technician because it was an unnecessary inspection step.

- Workload balancing to achieve a continuous processing flow

  The team increased the number of pharmacists who dispensed medications from two to three pharmacists. In addition, one pharmacy technician was assigned to help two pharmacists. In addition, one pharmacy technician was assigned to help two pharmacy technicians to enter medication orders.

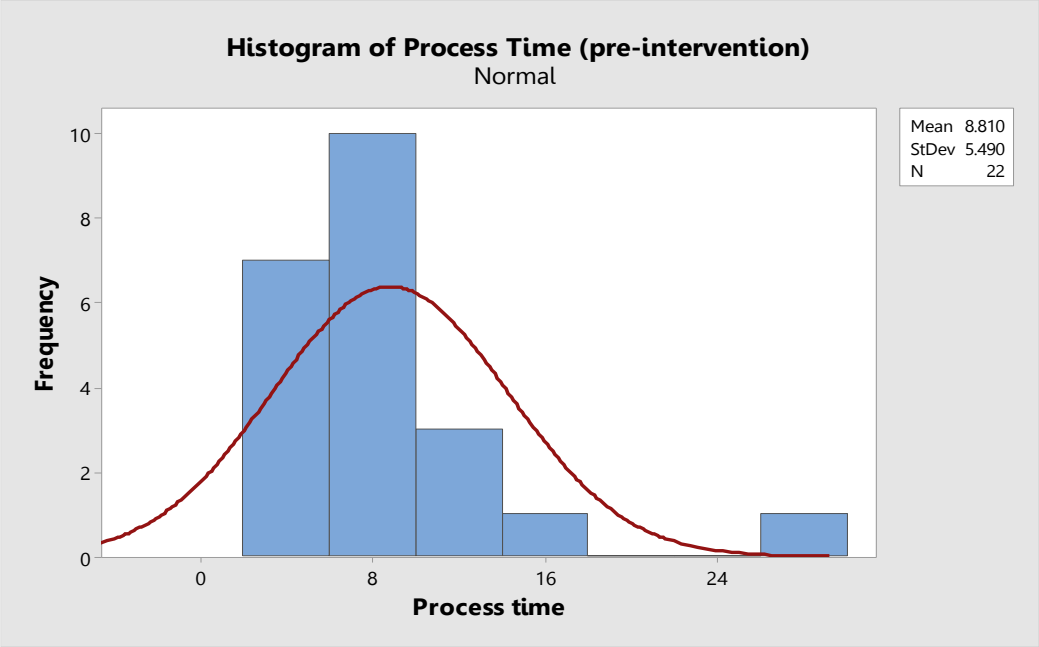


Figure 5.25 Histogram of process time before the improvements

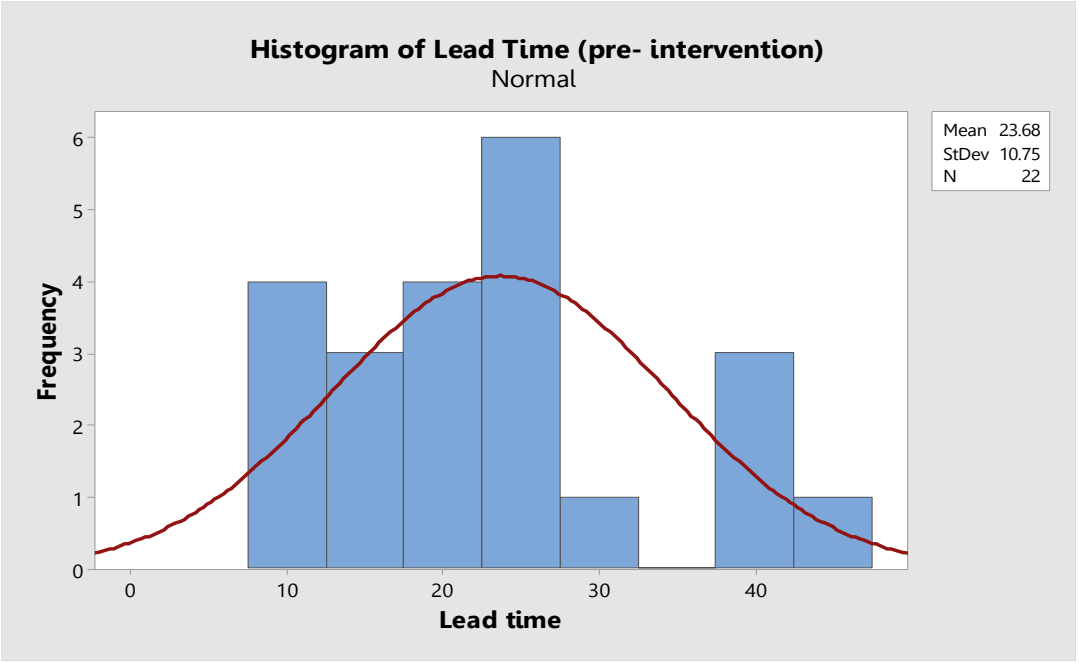


Figure 5.26 Histogram of lead time before the improvements

Afterwards, the team updated the new process flow when the above solutions had been implemented. As can be seen from Figure 5.27, the total lead time decreased from 41.56 to 29.46 minutes. The total process time decreased from 14.27 to 11.54 minutes.

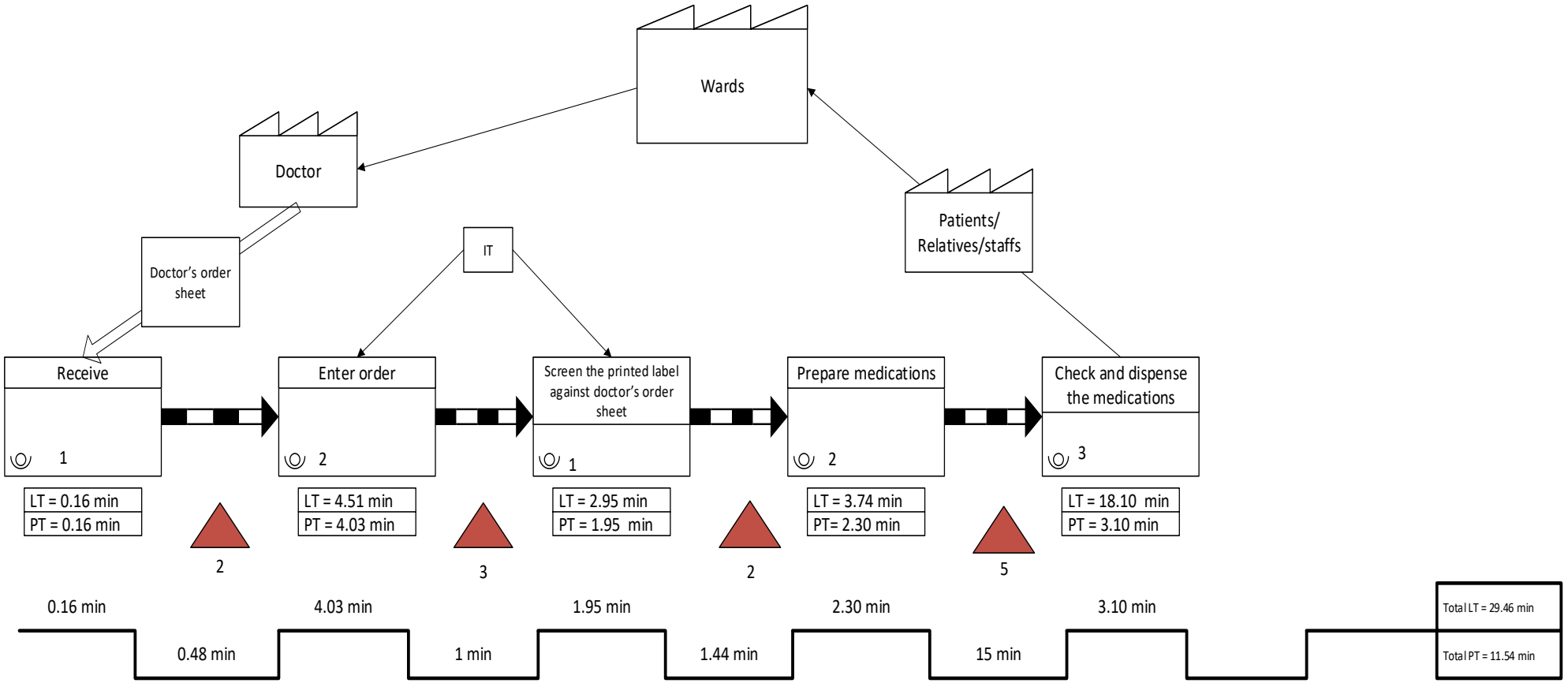


Figure 5.27 The improved state of three days dose dispensing process

Figures 5.28 and 5.29 show the histogram of process time and lead time after the solutions had been implemented. The average process time and lead time were 7.82 and 15.52 minutes respectively. The average standard deviation of the process time and lead time was 4.45 and 9.78 minutes respectively.

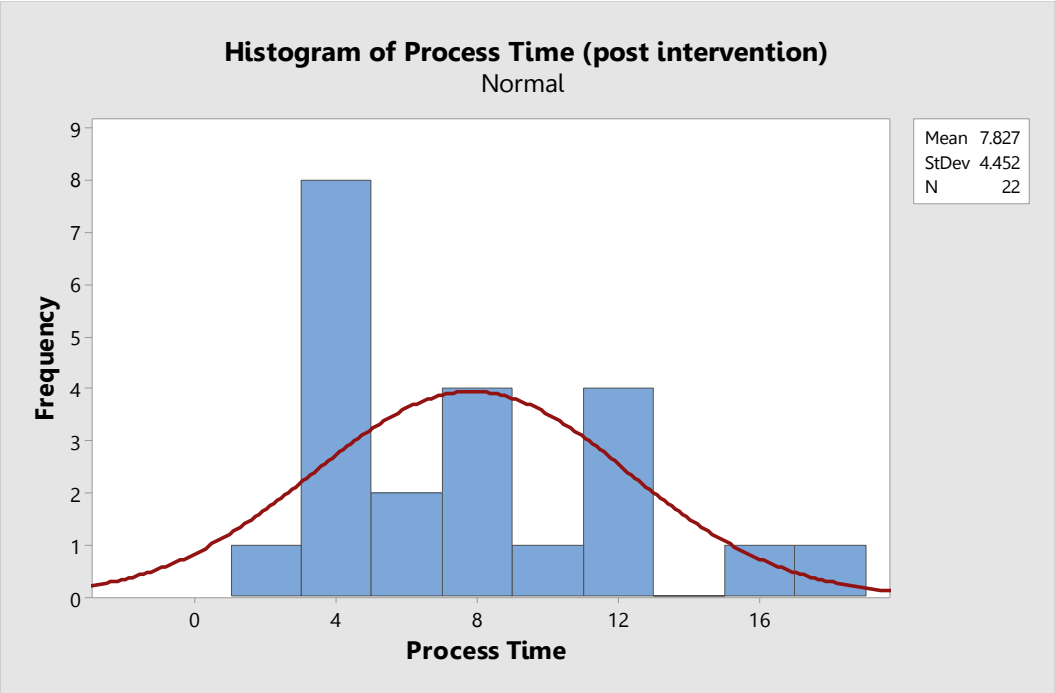


Figure 5.28 Histogram of process time after the improvements

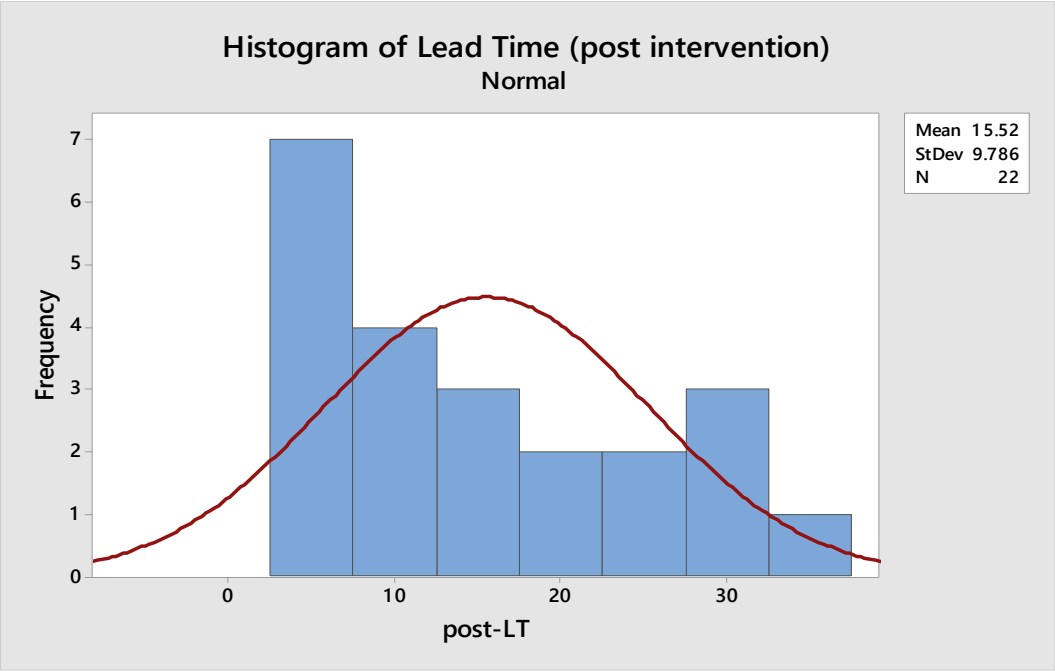


Figure 5.29 Histogram of lead time after the improvements

As a result of Lean application in the three days dose dispensing process, the average process time reduced from 8.81 minutes to 7.82 minutes and the standard deviation reduced to 4.45 from 5.49 minutes. Moreover, the average lead time reduced from 23.68 minutes to 15.52 minutes and the standard deviation was reduced from 10.75 to 9.78 minutes.

5.3 Challenges of LSS implementation in Hospital A

The main LSS implementation challenges encountered by the project team were lack of effective communication at all levels and resistance to change. These challenges are explained as follows.

5.3.1 Lack of effective communication at all levels

Lack of effective information sharing all levels of the inpatient pharmacy contributed to misunderstanding LSS implementation benefits. Although the project team members received training in LSS and its benefits prior to the project commencement, the remaining inpatient pharmacy staff lacked awareness of how LSS could improve their routine work. Contributing to this was inadequate information-sharing at all inpatient pharmacy levels. A participant described how this issue could affect the use of LSS:

> *'Poor communication between us (the project team) and other pharmacy technicians resulted in a lack of awareness of LSS implementation'.*

Another participant elaborated this issue, suggesting that it was not only ineffective communication in the inpatient pharmacy, but also with ward units:

> *'Due to poor communication between the inpatient pharmacy and wards, some nurses still did not understand why we needed to change the process'.*

5.3.2 Resistance to change

Resistance from pharmacy technicians was another main problem the project team encountered. Pharmacy technician agreement to routine task changes was difficult to secure, as they lacked trust and misunderstood the positive value of change. Hence, they resisted changes to routine work processes, as explained by the following pharmacists:

'Pharmacy technicians did not truly understand what we were going to change or adjust. So, they resisted the change because they thought that it might affect their routine job responsibilities'.

'Pharmacy technicians lacked confidence about the outcome of LSS implementation and whether it was going to improve their work or not. They wondered what was going to happen if we changed their routine working'.

'I (the researcher) felt that the pharmacy technicians do not want to change their routine working'.(Field notes)

'They thought that they were going to work more than usual, but they had to do because the head of the pharmacy service required them to take on more'. (Field notes)

A fear of change was another issue mentioned by participants.

'We were afraid of change because the solution would significantly change the medication preparation process. We were afraid that we could not prepare and fill medication without preparing it in advance. We also had to collaborate with several departments before we got the solutions. So, we thought that it was impossible to change'. (Fieldnotes)

'We did not want to change because we were afraid that we would have to do more jobs'. (Pharmacy technician)

'This was the nature of staff that they did not look at the bigger picture of the process, they only did their jobs based on what the leader assigned to them, without doing their own thinking. Also, LSS was intangible and staff were not familiar with it; therefore, they were afraid that they could not do it'. (Pharmacist)

Pharmacy technicians commonly adhered to their routine work and were unwilling to learn new methods. However, the next section identifies several factors, which helped the team to achieve the success of LSS project.

5.4 Critical success factors for LSS implementation in hospital A

Four main themes emerged as important factors leading to the success of LSS which included: leadership; creativity and problem-solving skills; understanding of LSS methodology and its tools and techniques, and middle management support and involvement. Each theme is explained as follows.

5.4.1 Leadership

With respect to leadership, the Head of Inpatient Pharmacy employed a transformational leadership approach to encourage and motivate the project team and to drive LSS initiative success. The Head of Inpatient Pharmacy was actively involved in the LSS project team and had a good ability to motivate the project team to ensure successful implementation of LSS. The following comment shows the leadership characteristics identified by the participants:

> *'We were lucky that we had her (the head of inpatient pharmacy); she always motivated us to collaborate with you (the researcher) through every phase of LSS methodology'.*

> *'If she (the head of inpatient pharmacy) had not been open-minded and receptive to the benefits of LSS, this project would not have succeeded'.*

The key characteristics of this transformational leadership included; problem-solving involvement, motivation, open-mindedness, and encouragement, all of which played important roles in successful LSS deployment.

5.4.2 Creativity and problem-solving skills

Project team members' creativity and problem-solving skills facilitated LSS implementation and contributed to project success. Participants described that the use of creative ideas to generate effective solutions and resolve problems was critical to success. Two participants commented:

> *'It was excellent that everyone in the team attempted to think creatively to produce solutions in the improve phase'.*

'If we could analyse the causes of the problems, but we lacked ideas to generate the solutions, how could we get the effective solutions to solve the problems?'.

This finding suggests that the value associated with selecting appropriately skilled team members to execute an LSS project for addressing medication process problems so that generating corrective actions to minimize effects of a selected root cause may require team members with creative thinking skills.

5.4.3 Understanding of LSS methodology and its tools and techniques

Some participants reported that understanding LSS and its tools and techniques was a key success factor of LSS implementation. Participants were familiar with all steps of DMAIC methodology and tools and techniques to be used in each phase of the methodology.

5.4.4 Middle management support and involvement

The participants reported that middle management support and involvement was another critical success factor leading to LSS project success. The Head of Inpatient Pharmacy had a high awareness of LSS, was actively engaged and dedicated in all of the LSS phases, and provided sufficient time for team members to execute the project. The project would not have been successful without the support and involvement of middle management who facilitated smooth running of the project. One of the participants described this:

'The project would not be running smoothly, if she (the head of inpatient pharmacy) did not participate and support us through the project. Her assistance through the project journey was important to us'.

'The inpatient dispensing process was very complex. If she (the head of inpatient pharmacy) had not paid attention to the implementation of LSS, this project would not have been embarked upon'.

Overall, this findings indicate that middle management support consisted of several elements (Psychogios *et al*., 2012). First, middle management should understand the needs for and benefits of the LSS methodology. Additionally, middle management is responsible for providing appropriate LSS project resources and being actively involved in all LSS deployment phases.

5.5 Reflection on the research process from the initial stage

Prior to applying the action research methodology, I felt anxious but excited to collaborate with participants in the healthcare setting because I was not familiar with this area. When I entered the inpatient pharmacy, I was feeling overwhelmed due to the busy environment, complex processes, ineffective layout and the fact that it was noisy. I was thinking 'how can they worked in this environment?' However, I felt more confident when I had begun to understand the medication distribution system in the inpatient pharmacy.

Gaining pharmacy technicians' agreement to make changes to their routine tasks was difficult. However, the relationship between me and participants as well as other staff in the inpatient pharmacy was getting closer as the project developed over time. The pharmacy technicians were eventually open-minded about accepting change because these changes made their life easier to complete their routine tasks. I felt that I had become a member of the inpatient pharmacy.

It was very challenging to introduce LSS methodology into the healthcare environment as most of the staff lacked awareness of quality improvement. Some of the participants had some knowledge of Lean, but none of the participants had any knowledge of, or had never heard about, Six Sigma. In order to overcome this difficulty, during LSS training, I provided an opportunity for all participants to ask questions and I spent time clarifying each question.

During each phase of the action research methodology, one of the main challenges I faced was participants' time commitment. It was difficult to arrange a meeting to conduct a focus group or interview with participants due to their limited time. However, the Head of Inpatient Pharmacy arranged meetings for me with participants, which were held mostly in the lunchtime. During the brainstorming session, participants were very cooperative and keen to generate solutions. When the potential solutions were identified to tackle the selected root causes, I felt that these solutions could be implemented immediately. However, as this was not what I was expecting, it took time to implement the solutions. For example, it took several steps to develop a guideline for the delivery of STAT medications. The participants had to arrange a meeting with the Pharmaceutical and Therapeutic Committee (PTC). Before implementation, the Medical Staff Organization Committee had to approve this guideline. Moreover, some potential solutions generated during the brainstorming session could not be implemented, if they were related to the actions of doctors due to the culture of healthcare in Thailand.

At the end of the project, I was very happy with the results and the major changes in the dispensing process. I was grateful that the staff had a better working life and I felt lucky that the participants had always supported throughout the project.

5.6 Key lessons learnt

The key lessons identified from the implementation of LSS through the action research methodology were as follows:

- The engagement of all staff members across the pharmacy service and the support from the Head of Inpatient Pharmacy was a key success factor in this project.
- Prior to the project, it is important to ensure that everyone in the inpatient pharmacy understands LSS importance and how its application could improve the existing process. Not only should participants receive LSS training, but also all the staff in the department should have a fundamental knowledge of LSS and its tools and techniques.
- A positive feature for the hospital is that the data are available to access and use. In the past, decisions taken to solve the problems were mostly based on pharmacists' opinions and ideas. Following the project, the participants were able to make decisions to solve the problems based on data and facts.
- Major change in the dispensing process could be achieved simply and without major investment. However, when potential root causes are identified, it is important to verify their importance, and that implemented corrective actions work effectively to reduce the problem impacts.
- There are factors that cannot be controlled such as participants' having time while the action research methodology is conducted. The action research methodology is not suitable for projects that need to be completed within a set period of time.
- Action research may require significantly more time and effort on the part of the researcher than other research approaches (Kock, 2003).
- A good relationship between the researcher and practitioners throughout the project is vital for successful LSS implementation.

5.7 Chapter summary

The findings indicate that the collaboration between researcher and participants enabled several changes to be made and resulted in improvement in the dispensing process (both daily dose and three days dose distribution system). Through the key phases of action

research methodology, the problems that created dispensing errors were identified and addressed.

As part of the action research methodology, the research was conducted successfully through the application of LSS methodology along with its tools and techniques. The implementation of LSS provided the solutions that minimized the effect of the selected root causes and resulted in improvement and less variability in the existing dispensing process. The average proportion of undetected dispensing errors reduced from 0.002 to 0.0007, representing a 65 per cent reduction. Moreover, the most frequent type of incorrect selection of medication and incorrect entry of medication orders was reduced after the implementation of LSS.

The dispensing process flow was improved due to the elimination of non-value added activities during medication preparation. The improved daily dose medication preparation process decreased the workload for many of the staff, which in turn helped them to complete their tasks more easily. Moreover, the employment of LSS through action research methodology had enabled greater understanding and improved communication channels between pharmacists and pharmacy technicians, as well as increasing staff satisfaction and enhancing patient safety.

Lean methodology was successfully implemented to reduce the waiting time associated with three days dose distribution system. The application of Lean tools such as VSM could eliminate non-value added activities that contribute to delays in dispensing medication to patients' relatives. The results revealed decreased waiting time and improved workflow.

The project increased awareness of participants and staff to continuously implement LSS methodology and its tools and techniques to other areas in the pharmacy services and departments in the hospitals. The lack of communication at all levels and resistance to change created specific challenges during LSS implementation. However, the support and involvement of middle management, the leadership, and creativity and problem-solving skills were key LSS implementation success factors.

CHAPTER 6 – ACTION RESEARCH FINDINGS FROM HOSPITAL B

6.1 Introduction

This chapter presents the findings from the action research which was undertaken in the inpatient pharmacy in Hospital B. The findings are presented following the key phases of action research methodology. In **Phase one**, the key problem in the medication dispensing process is identified. **Phase two** is involved with reflection on the identified problem. **Phase three** is related to the planning of an intervention and participants attending the LSS training. The team further implemented LSS in **Phase four**. Following the implementation, the project is evaluated and reflected upon by the participants **in Phase five.** The lessons learnt as perceived by the participants are identified in **Phase six.** Challenges and critical success factors for the implementation of LSS in the inpatient pharmacy as perceived by the participants, are further identified. Finally, reflections and key lessons learnt by the researcher regarding the research process throughout all phases are presented.

6.2 Case study on action research methodology: Hospital B

The following sections present the key findings based on the key phases of action research: identification of the problems, reflection, planning action, taking actions, evaluation and reflection, and specifying lessons learnt.

Phase 1: Identification of problem

After the completion of the focus group and process mapping, a main problem was identified: the incorrect selection of medications by pharmacy technicians. This was the main process problem that created dispensing errors. A more detailed of this problem is described as follows.

Problem: Incorrect selection of medications

Incorrect selection of medications from the shelves by pharmacy technicians was the main problem leading to the occurrence of dispensing errors. Pharmacists described it in this way:

'The pharmacy technicians did not collect medication based on the location identified in the medication label. They collected medications based on their experience and familiarity'. (Focus group, Pharmacist)

'The pharmacy technicians worked rapidly. They collected medications without carefully reading the medication labels'. (Focus group, Pharmacist)

'The pharmacy technicians quickly selected medications from the shelves, particularly senior pharmacy technicians who have been working in the inpatient pharmacy for many years'. (Field notes)

Pharmacy technicians further described working behaviours that contributed to the occurrence of dispensing errors as follows:

'When I worked at speed, I only read the name of medications and did not read the strength of such medications'. I had to perform many tasks during a day'. (Field notes)

'While I was collecting medications, I had to collect the prepared home medications when it was required by the front counter pharmacists to dispense to the patients' relatives. I lose concentration when switching attention between tasks and this leads to the incorrect selection of medications'. (Focus group, Pharmacy technician)

However, a positive feature of the inpatient pharmacy environment is the well-organised workplace and its cleanliness.

'The medications are stored and kept well organised. The label attached to the containers is big and easy to read. Moreover, proper lighting and a comfortable temperature can improve the performance of the pharmacy technicians and minimize the risk of dispensing errors'. (Field notes)

The identified problem was further reflected upon by participants in the next phase in order to make a decision about which problems could continue to be resolved or would need to be redefined.

Phase 2: Reflection

In this phase, the researcher presented the problem identified from phase 1 to the participants. Process mapping was presented to the participants and explained in detail. More details of such a tool were explained in the 'taking action' phase. After the

presentation, the participants indicated they would like to solve the problem. The team decided to focus on the medication selection process step. Several participants mentioned the desired process improvement outcomes:

> *'This project could reduce the number of dispensing errors because the problem remains in the inpatient pharmacy'. (Field notes)*
>
> *'We would like to cooperate with you (the researcher) because you were the outsider researcher who could help us to solve the problem and reduce the number of dispensing errors'. (Field notes)*

However, one of the participants argued that the implementation of LSS to reduce the occurrence of dispensing errors may be difficult. She explained:

> *'I could not think of any solutions to reduce the number of dispensing errors, even though I have experience and have worked in the inpatient pharmacy for many years'. (Field notes)*
>
> *'I (the researcher) felt that might be the reason that the team have to follow DMAIC methodology might be because the solutions of the problem are not obvious and you could not envisage the solutions'. (Field notes)*

In addition, it is important to note that the flow of the dispensing process is simple because the hospital had implemented Lean across the organization since 2008 and it became a Lean enterprise in 2010. For the inpatient pharmacy, Lean tools such as spaghetti diagram, visual management, and 5S have been implemented to improve the flow of dispensing process. Moreover, the CPOE has been implemented instead of handwritten medication orders in all wards in the hospital since 2004 (Nualsri, 2006).

Phase 3: Planning action

In this phase, the aim was to plan an intervention by ascertaining which interventions could be used to solve the problem identified in the first phase. Based on the action research model in chapter 3, the key question to ask, having decided to implement LSS methodology to solve the identified problem, was as follows:

(1) Are the solutions unknown and at the same time, is there an element of variation and waste?

Based on the question, the solutions for solving the incorrect medication selection were unknown. Variation also existed in a control chart, which was presented in the taking

action phase. The participants had implemented several approaches, such as using 'tall man letter' to differentiate the 'look alike sound alike medications' (Figure 6.1), changing medication labels and promoting awareness of staff about good practice on collecting and dispensing medications. However, the root causes of the problem still remained in the process and could not be resolved. In addition, there were non-value added activities in the dispensing process such as waiting for pharmacy technicians to prepare medications. Moreover, there was a medication preparation standard procedure, but it was not being followed by the pharmacy technicians. Therefore, Lean tools were integrated in Six Sigma methodology to solve the problem.

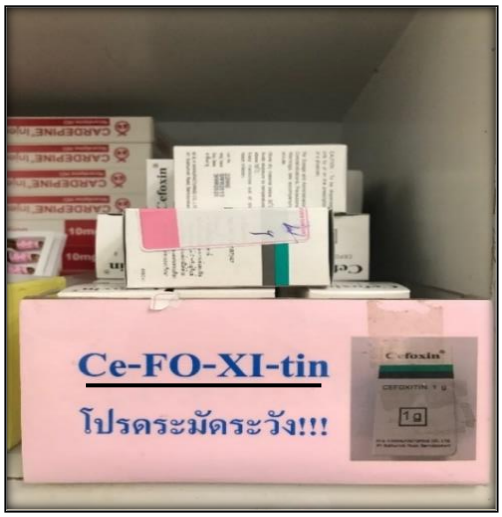


Figure 6.1 Tall man lettering (the writing of a medication's name in upper case letter)

The researcher conducted three hours of LSS training in the inpatient pharmacy. The training had an open invitation and four pharmacists who were not members of the action research team also attended (Waterman *et al*., 2005b). The details of LSS training were the same as 'planning action phase' described in Chapter 5. The table below presents action plans to achieve solutions to the problem identified from the first phase. After that, these activities were implemented in the next phase.

Table 6.1 LSS methodology planning actions

Problem	LSS Methodology	Start	Finish
Incorrect selection of medications	Define Phase	5 Apr 2018	31 May 2018
	Measure Phase	1 Jun 2018	31 Jul 2018
	Analyse Phase	1 Aug 2018	31 Aug 2019
	Improve Phase	1 Sep 2018	31 Dec 2018
	Control Phase	1 Jan 2019	31 Dec 2019

Phase 4: Taking action

In this phase, the team followed DMAIC methodology and applied several Lean and Six Sigma tools and techniques to each phase of the methodology.

1) Define phase

This phase aims to identify the projects scope and goal and to define the problem (Antony *et al*., 2016; Bhat *et al*., 2016). A project team was formed which included: the researcher, the Head of Pharmacy Department, the Head of Pharmacy Service, the Head of Inpatient Pharmacy, the pharmacist and three pharmacy technicians. After that, a project charter was prepared to help the team to focus on the project goal and clarify the roles and responsibilities of each team member, as presented in Table 6.2 (Bhat *et al*., 2014).

Table 6.2 Project charter

<table>
<tr><th colspan="3">Project Charter</th></tr>
<tr><td colspan="3"></td></tr>
<tr><th colspan="2">Customer(s)</th><th>Customer CTQ</th></tr>
<tr><td colspan="2">Inpatients</td><td>Number of dispensing errors</td></tr>
<tr><th colspan="2">Problem Statement</th><th>Potential Benefits</th></tr>
<tr><td colspan="2">Dispensing errors occurred daily especially in the busy period in the inpatient pharmacy. The average number of dispensing errors that could not be detected by the pharmacists between April 2017-April 2018 was five errors. The dispensing errors could lead to patient and death and contribute to increase in hospital cost.</td><td>Reduce dispensing errors, improve patient safety and staff satisfaction</td></tr>
<tr><th colspan="2">Goal Statement</th><th>Project scope</th></tr>
<tr><td colspan="2">The goal is to reduce the number of dispensing errors in an inpatient pharmacy by 50%.</td><td>The pharmacy technicians receive medication labels and medications are delivered to different wards and dispensed to the patients.</td></tr>
<tr><th colspan="2">Schedule</th><th>Potential Team Members</th></tr>
<tr><td>Phase</td><td>Start Finish</td><td rowspan="6">Team leader: Researcher
Team members: Head of Pharmacy Department
Head of Pharmacy Service
Head of Inpatient Pharmacy
Pharmacist
Pharmacy technician 1
Pharmacy technician 2
Pharmacy technician 3</td></tr>
<tr><td>Define</td><td>Apr 2018 May 2018</td></tr>
<tr><td>Measure</td><td>Jun 2018 Jul 2018</td></tr>
<tr><td>Analyse</td><td>Jul 2018 Aug 2018</td></tr>
<tr><td>Improve</td><td>Sep 2018 Dec 2018</td></tr>
<tr><td>Control</td><td>Jan 2019 Dec 2019</td></tr>
</table>

In the next step, an In Frame/Out of Frame tool was used to ensure that the project had a clear scope (Figure 6.2). The tool helped the team to have a clear understanding of the project scope.

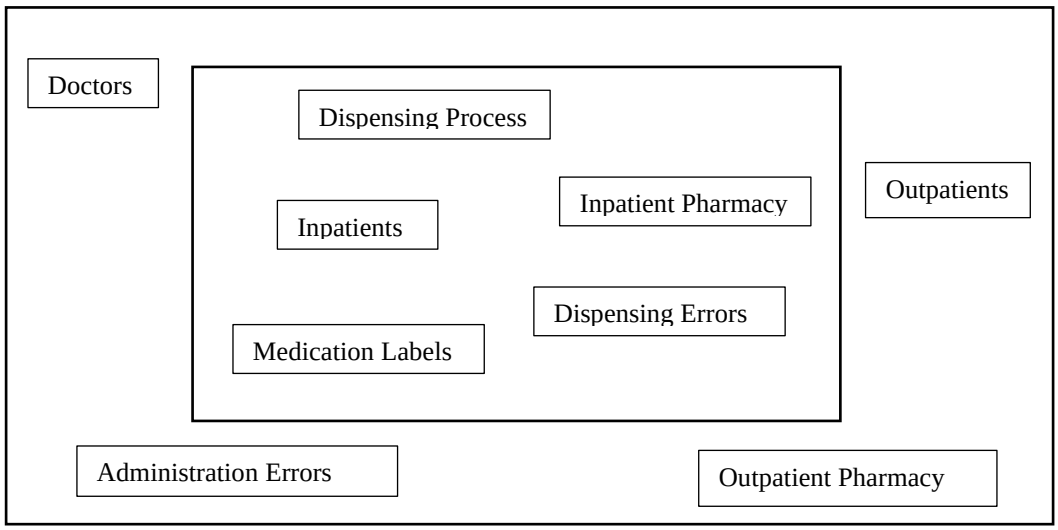


Figure 6.2 In Frame/Out of Frame tool

After that, the project team used process mapping to identify the problem within the dispensing process. Figure 6.3 shows the flow map of the dispensing process. The researcher walked in both directions through the dispensing process (backwards and then forwards) twice a day in order to understand what had occurred in each of the process steps. During the walks, the researcher examined how medication flowed from one workstation to the next. The researcher also observed the activities and talked to those staff who were involved in each process step. The researcher collaborated with the participants to create an as-is dispensing process map. This process map includes six main steps:

1) the medication labels are received by pharmacy technicians;
2) the pharmacy technicians select medications based on each medication label;
3) the prepared medications are first checked by a pharmacy technician who was not involved in selecting the medications;
4) the prepared medications are double-checked by a pharmacist;
5) all of the prepared medications are arranged in different ward baskets
6) the medications are delivered to different wards, except for the home medications which are dispensed to the patient's relatives by front counter pharmacists.

The team agreed that incorrect selection of medications by pharmacy technicians contributed to the dispensing errors. There was also an unnecessary rework loop when

pharmacists double-checked the medications and found there was a difference between the prepared medications and medication labels. As a consequence, pharmacy technicians had to change medications and then select the correct one.

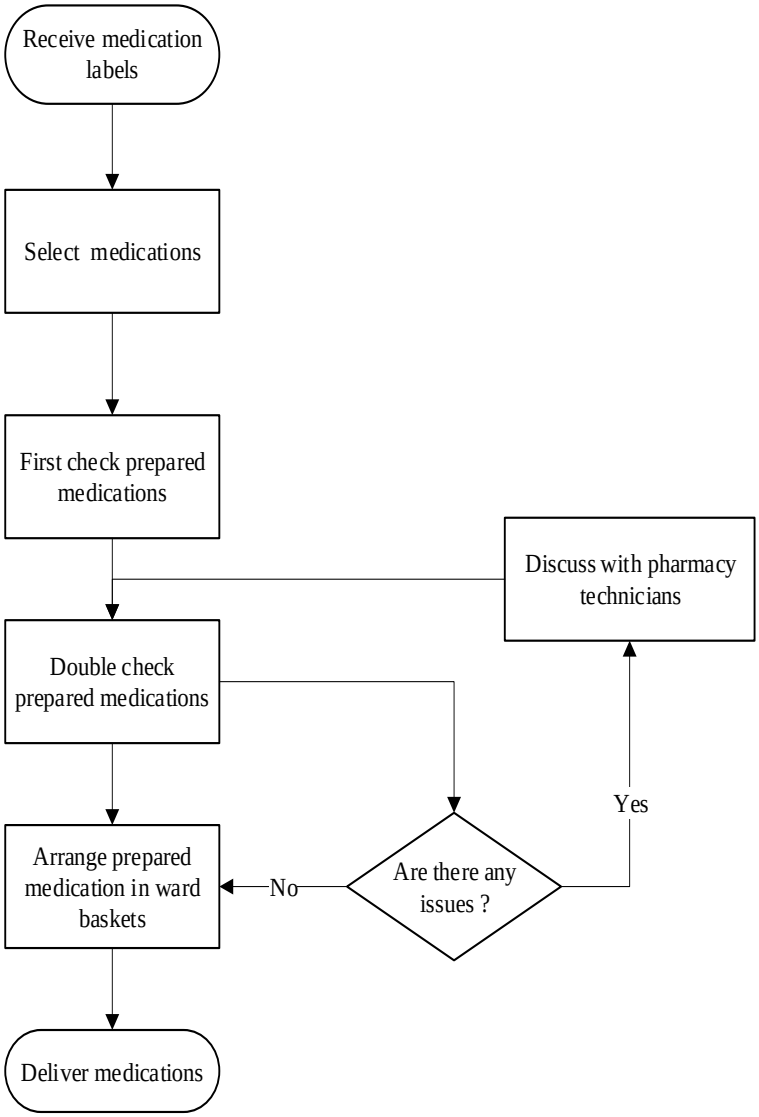


Figure 6.3 A flow map of dispensing process

- Problem statement

A problem statement was developed based on the problem statement matrix (Table 6.3) to define and understand the problem. The problem statement specified that the incorrect selection of medications was recognised as the main process problem which resulted in dispensing errors. The errors resulting from the incorrect selection of medications occurred daily especially in the busy period (8-11 am) and break time (12-2 pm). The identified process problem needed to be improved in order to reduce variations in the process of dispensing medicine mitigate against potentially harming the patients (or even causing death) and financial costs to the hospital.

Table 6.3 The problem statement matrix

Questions	Explanation
What is wrong?	Pharmacy technicians selected incorrect medications from the shelves and passed to the pharmacists. If these medications were not detected by the pharmacists, they could reach the inpatients.
Where does the problem appear?	In the dispensing process
When does the problem appear?	Daily especially in the busy period and break time due to a lack of staff
How big is the problem?	Patient injury and death and it contributes to increase in hospital cost.

2) Measure Phase

This phase aims to gather the data from the current process to understand the baseline performance of the dispensing process (Sanders and Karr, 2015). A data collection plan was developed to ensure that the team collected appropriate and reliable data (Table 6.4) (George *et al*., 2005). The project team defined the CTQ characteristics as the errors that were undetected by the pharmacists in the inpatient pharmacy. The number of dispensing errors was collected to assess the performance of the dispensing process. Then, to measure the baseline performance of the dispensing process, the team divided the measure into process measure and output measure. The number of errors in the medication selection which were detected by the pharmacists were collected for the process measure. The errors which were undetected by the pharmacists were collected for output measure.

Table 6.4 Data collection plan

Metric	Type of Measure	Type of data	Operational definition	Source of data	Collection method
detected dispensing errors	Process	Discrete (counts of errors)	The errors that occurred in the process step that were detected by the pharmacists.	Hospital information system	Pharmacists report to hospital information system.
undetected dispensing errors	Output	Discrete (counts of errors)	The errors that occurred at the end of dispensing process which were undetected by the pharmacists.	Hospital information system	Nurses report to hospital information system.

The team were able to access the data from the hospital information system for both types of measure. For process measure, the pharmacists collected the number of incorrect medication selection daily. When they found the errors, they could directly entered the data in the hospital information system. The proportion of incorrect medication selection was plotted on a P-chart for a twenty-five-month period from December 2016 - December 2018. Figure 6.4 shows that the process was unstable because 2 points fell beyond 2σ from the centre line. The average proportion of incorrect medication selection was 0.0026 and this provided the baseline data.

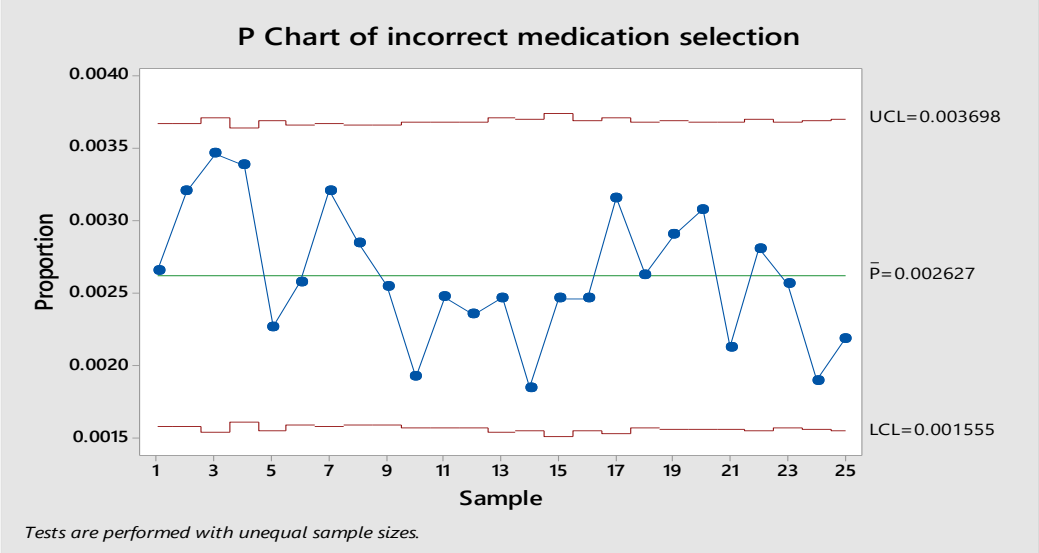


Figure 6.4 P-chart of proportion of incorrect medication selection per month

For output measure, the dispensing errors detected by the nurses had been reported to the hospital information system daily. The nurses were trained to report the number of errors to ensure that the measurement of dispensing errors was valid and accurate. The errors were plotted on a P-chart for a twenty-five-month period from December 2016 - December 2018. Figure 6.5 shows that the average proportion of undetected dispensing errors was approximately 0.0003. This was considered as a baseline performance of the dispensing process. The result showed that the dispensing process was out of control because nine points were in a row on the same side of the centre line. This dispensing process was unstable and showed variation. This may have been due to errors caused by newly trained staff or as a result of inadequate resourcing at peak times and break times. In order to reduce process variation and improve the dispensing process performance, the root causes of the problem are identified in the next phase.

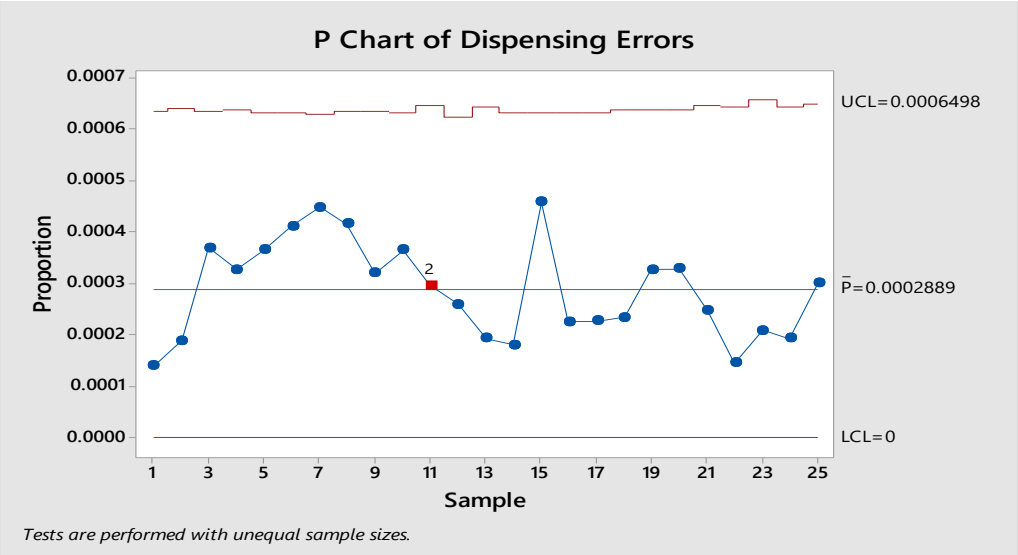


Figure 6.5 P-chart of proportion of undetected dispensing errors per month

Furthermore, medication selection errors were collected and visually displayed in a Pareto diagram (Elbireer *et al.*, 2013) to compare the rate of occurrence before and after the implementation of LSS. Figure 6.6 shows that more than 80% of medication selection errors made by pharmacy technicians were associated with the selection of the wrong quantity (29 errors) and wrong medication (28 errors).

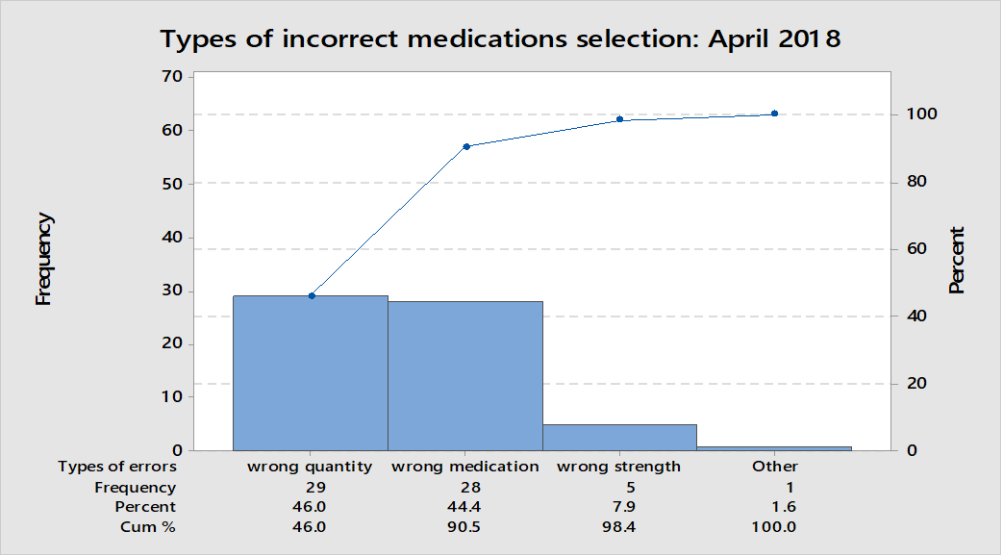


Figure 6.6 Types of incorrect medication selection

3) Analyse Phase

This phase aims to identify the potential root causes of the problem. The participants held a brainstorming session to identify the potential causes of incorrect medication selection. All of the potential causes of these problems were then visually presented in a cause and

effect diagram (Figure 6.7). After that, the identified potential causes were prioritized into the three most prevalent causes by using a multi-voting tool.

Problem: Incorrect selection of medications

Figure 6.7 shows the potential causes of incorrect selection of medications. These included: non-compliance with medications' selection standard procedure, being too rushed, workload, returning medications from wards, inadequate drug storage and pharmacy technicians did not keep tablet bottles in place after using them. Such potential causes were further categorised into three main categories: Methods; Environment and Personnel. The following will explain the details of each potential cause.

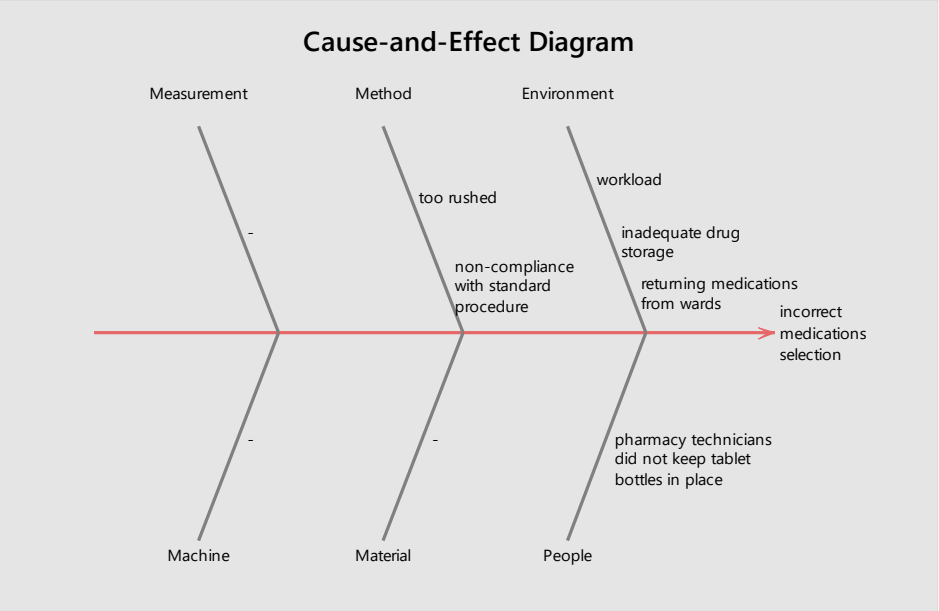


Figure 6.7 Cause and effect diagram of incorrect medication selection

Method

- Non-compliance with standard procedures for medication selection

The primary steps of medication selection were reading medication labels sufficient and collecting medication based on the medications' locations identified on the medication labels. There was a medication selection standard procedure attached to the shelves. However, the pharmacy technicians were not following this procedure. They collected medications from shelves based on their experience and familiarity of medication locations. The pharmacy technicians collected medications without carefully reading the medication name and strength. One of the participants explained the reason why pharmacy technicians were not following the standard procedure:

'Most of the pharmacy technicians had been working in the pharmacy service for more than ten years. They collected medications according to their experience and familiarity. They did not collect medications from the locations identified on the medication labels'. (Field notes).

Another participant explained:

'I (senior pharmacy technician) only collect medications based on the locations when there are new medications'. (Field notes)

The researcher reflected that:

'The pharmacy technicians rapidly collect medications from the shelves. It seems that they could remember the positions of medications'. (Field notes)

- Too rushed

Each pharmacy technician had to prepare different types of medications daily. There was a key performance index agreed between the pharmacy service and wards that STAT medications and new order medications should be administered to the patient within 30 minutes and one hour, respectively. Moreover, the preparation of continuous medications needed to be finished before 12.00 pm, and then delivered to 38 wards in the afternoon.

The pharmacy technicians were not only preparing medications, but they also had other tasks to complete during a day such as checking returned medications from wards and contacting the medications' store. Therefore, they were rushing to collect medications, and this contributed to the incorrect selection of medications. Two pharmacy technicians described their routine working as follows:

'I quickly collected the medications because I was familiar with medications and their locations'. (Field notes).

'In the morning, it was very busy. I was rushing to finish preparing medications because I had other tasks to complete during a day (e.g. consult with wards and preparing morphine)'. (Field notes).

The researcher further reflected this situation as follows:

'The pharmacy technicians quickly prepare medications, a lot of prepared medications are waiting to be checked and dispensed by the pharmacists. If the pharmacy technicians select the correct medication the first time, it is not necessary to check the prepared medications again'. (Field notes)

Environment

- Workload

Excessive workload and time pressure could affect the performance of pharmacy technicians when they collected medications. The pharmacy technicians were standing up all day long to collect medications and only had time off for a lunch break. Due to insufficient staff, each pharmacy technician had to complete many tasks during a day. Staff workload can increase the opportunity of selecting wrong medications. Pharmacy technicians expressed their views about the workload they had:

> *'We (pharmacy technicians) have multiple responsibilities to accomplish during a day. I thought that we received more work to do than the number of staff'. (Field notes)*

One of the participants further suggested that:

> *'If the head of pharmacy department could reduce the amount of work, we could have more time to read medication labels when collecting medications'. (Field notes)*

- Returning medications from wards

Everyday a lot of unused medications from the wards were returned to the pharmacy service. Pharmacy technicians had to check the package of each returned medication and place it back on the shelves to ensure that the medications were correct. If the pharmacy technicians did not return medications to the right location, this could result in selecting wrong medications. Moreover, the returning of medications from wards increased the workload of pharmacy technicians. Participants explained:

> *'Sometimes, nurses have already used the medications and they returned these medications to us. If we (pharmacy technicians) did not carefully check the returning medications, we could collect the wrong medications'. (Field notes)*

One of the participants also mentioned this problem:

> *'If nurses were to carefully check the medications that have not been administered to the patients, I could have more time to select medications'. (Field notes)*

- Inadequate drug storage

Due to the limited space in the inpatient pharmacy, the shelves and stock containers were insufficient. Therefore, one location consisted of several medications and this could increase the risk of selecting wrong medications.

Personnel

- Pharmacy technicians did not keep tablet bottles in place after using

Pharmacy technicians quickly collected the medications. As shown in Figure 6.8, after the pharmacy technicians had counted the tablets from the drug tablet bottles, they did not place these bottles in the correct location on the shelves. All bottles were placed close to each other on the workspace, and this could lead to the incorrect selection of the wrong tablet bottles.

Figure 6.8 Medication bottles on the workspace

Afterwards, multi-voting tool prioritized the three most prevalent causes: being too rushed, non-compliance with the standard medication selection procedures, and workload (Table 6.5). The team further used 5 Why analysis to identify the root causes of each of the three potential causes (Table 6.6) (Kieran *et al*., 2017). The Head of Inpatient Pharmacy asked as a team facilitator who asked why the problem had happened and recorded the participants' responses. The team facilitator continued to ask why until there was agreement from the participants that the root cause had been identified. After using 5 why analysis, the root cause of these problems was identified as the unbalanced workload between each position of pharmacy technicians who collected the medications.

Table 6.5 The top three causes of incorrect medications selection

Causes	Total Score	Ranking
1. Non-compliance with medications' selection standard procedure	2+1+1+1+1=6	2
2. Too rushed	1+2+2+2+2+2=11	1
3. Workload	1	3
4. Returning medications from wards	0	4
5. Inadequate drug storage	0	4
6. Pharmacy technicians did not keep tablet bottles in place after using	0	4

Table 6.6 5 Why analysis identifying the root cause of incorrect medication selection

Causes of incorrect selection of medication	1st Why	2nd Why	3rd Why	4th Why	5th Why
1. Too rushed	Staff had to perform several tasks during a day	Unbalanced workload between each position of pharmacy technicians who collected the medications			
2. Non-compliance with the standard procedures	Too rushed	Staff had to perform several tasks during a day	Unbalanced workload between each position of pharmacy technicians who collected the medications		
3.Workload	Unbalanced tasks between each position of pharmacy technicians who collected the medications				

4) Improve Phase

Once the root causes were identified, the team conducted a brainstorming session to generate potential solutions for the selected root cause (Elbireer *et al*., 2013) and then implemented the most appropriate solutions (Gijo *et al*., 2018). Table 6.7 presents the potential solution which was identified to minimize the effect of the root cause when incorrect medication was selected. Evenly distributing the workload was the best possible solution generated by participants based on ease of implementation and cost associated with implementation. Following this, the team prepared a follow-plan together with

responsibility and target dates for the completion of the solution (Table 6.8). The potential solution was implemented for two months.

Table 6.7 Potential solution to minimize each selected root cause

Potential causes of incorrect medication selection	Root Causes	Potential Solution	Follow–up plan
1. Too rushed	Unbalanced workload between each position of collecting medications	Evenly distribute the workload by reassigning tasks for pharmacy technicians	The Head of Inpatient Pharmacy checks every week to ensure the staff have followed the new procedures.
2. Non-compliances the recommended procedures medication when they pick the medications	Unbalanced workload between each position of pharmacy technician who collected the medications	Evenly balance the workload by reassign tasks for pharmacy technicians	The Head of Inpatient Pharmacy checks every week to ensure the staff have followed the new procedures.
3.Workload	Unbalanced tasks between each position of pharmacy technicians who collected the medications	Evenly balance the workload by reassign tasks for pharmacy technicians	The Head of Inpatient Pharmacy checks every week to ensure the staff have followed the new procedures.

Table 6.8 Implementation plan for selected root cause

Implementation Plan		
Potential solution	**Persons responsible**	**Due date**
Balance the workload by reassigning tasks for pharmacy technicians	Action research team	1 Oct 2018

The following is an explanation of the potential solution identified in Table 6.8 which was in turn used to minimize root cause.

- Evenly distribute the workload

The team decided to reassign tasks for the pharmacy technicians in order to balance the workload of each location, as shown in Figure 6.9.

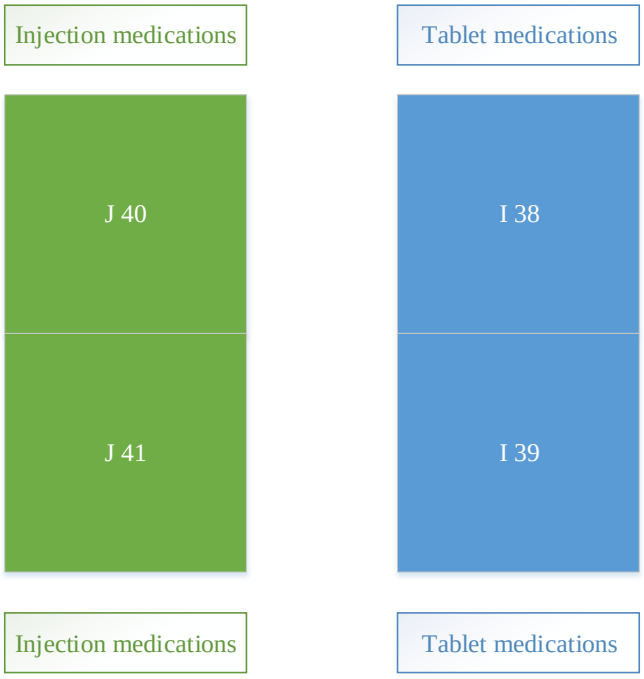


Figure 6.9 Four locations for selecting medications from shelves

Two of pharmacy technicians who were in the action research team arranged a meeting with the other pharmacy technicians. The staff who were not team members explained the current workload which was unbalanced between each location. Afterwards, the pharmacy technicians fed the data back to the action research team. The workload distribution was finally identified as follows:

Location J 40

The following tasks were the additional work for the third pharmacy technician in this location.

- Select injection medication from 12.00 - 1.00 pm and 2.00 - 2.30 pm.
- Deliver total parenteral nutrition, TPN ("TPN; a food replacement given to patients who are not able to eat", Jackson and Wilson, 2005, p.68) to different wards

Location I 38

- As the doctor's ward round is normally early in the morning, a high number of medication is ordered. The second pharmacy technician usually selects and delivers medication between 8.30 am and 9.00 am. The team decided to change the medication selection time to 8.30-8.45 am as the second pharmacy technician could assist the first pharmacy technician with the medication selection and delivery process during 8.45 – 9.00 am period.

Location I 39

The following is the additional work allocated to the second pharmacy technician in this location.

- Generally, the first pharmacy technician selected the medication during lunchtime. The team decided to assign a second pharmacy technician to select the required medications during the 12.00-1.00 pm period. Moreover, the team decided to increase the number of pharmacy technicians in this location from two to three pharmacy technicians. The followings show the detail of work assigned for the pharmacy technician who had been allocated to this location.
    - 8.30 -12.00 pm

        1) Distribute prepared medications to staff from wards
        2) Put the prepared medications into ward baskets

    - 1.00 - 4.30 pm

        1) Select medications from Location I39
        2) Distribute medication labels to pharmacy technicians who respond for selection of medications at different locations
        3) Check total parenteral nutrition (TPN) and call to wards to collect the TPN

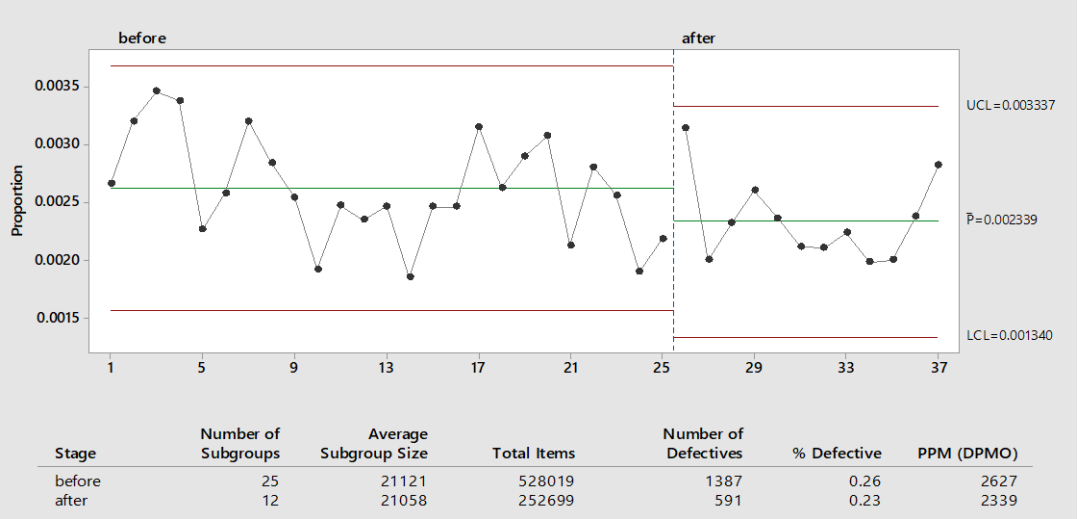
5) Control phase

To ensure that the improvement was sustained, the following measures were taken into account:

- **Standard operating procedures (SOPs) development**
  The medication selection SOPs were placed near the pharmacy technicians' workstation. The SOPs provided the details of the task descriptions in each location, in addition to identifying the responsible person. The staff in the inpatient pharmacy were trained on how to use the SOPs to ensure that all staff understood and followed instructions correctly. After the SOPs were implemented, it was evaluated and updated every month by a team member. Moreover, staff were monitored regularly by the Head of Inpatient Pharmacy to ensure that they followed the SOPs.

- **Statistical process control implementation**

  For monitoring the dispensing process after improvement, the researcher continued to collect the data over the next 12 months (January-December 2019). Figure 6.10 compares the average proportion of errors in medication selection before and after the improvements. The result shows that the average proportion of incorrect medication selection was reduced from 0.0026 to 0.0023 after the changes have been implemented.

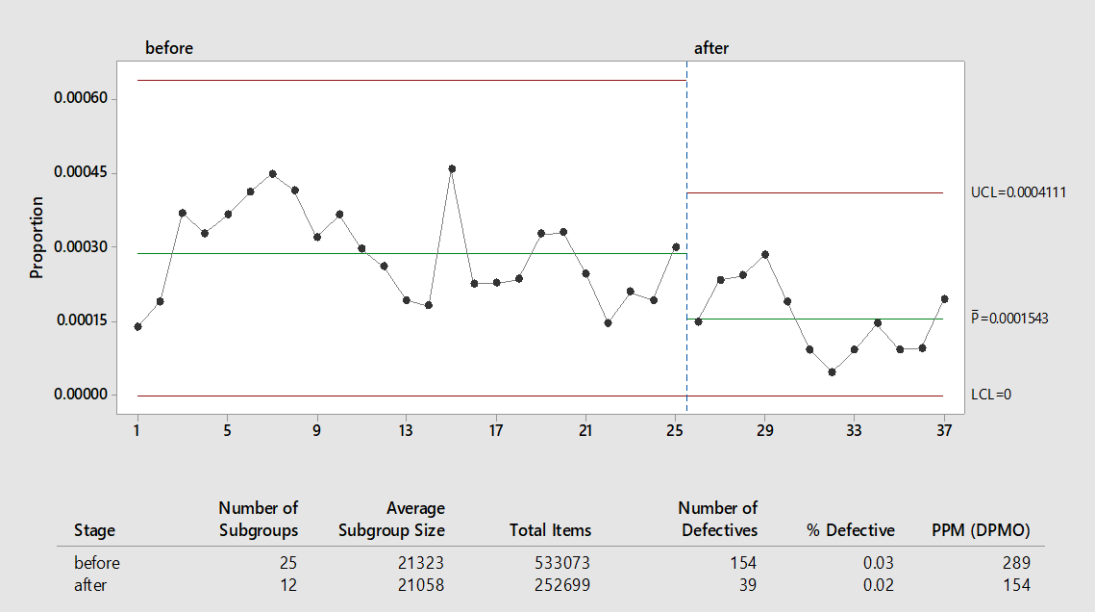


Stage	Number of Subgroups	Average Subgroup Size	Total Items	Number of Defectives	% Defective	PPM (DPMO)
before	25	21121	528019	1387	0.26	2627
after	12	21058	252699	591	0.23	2339

Figure 6.10 P-chart of incorrect medication selection before and after the improvements

As a result of the improvements, the dispensing process started to behave as an in control process (Figure 6.9). The average proportion of undetected dispensing errors significantly reduced from 0.0003 to 0.0002. The variation of the dispensing process was considerably reduced. Moreover, the number of dispensing errors reduced from 6 in April 2018 to 3 errors in December 2019 over 20,000 total inpatient days per month. This represented a 50% reduction. Comparison of results before and after the improvements are summarised in Table 6.11.

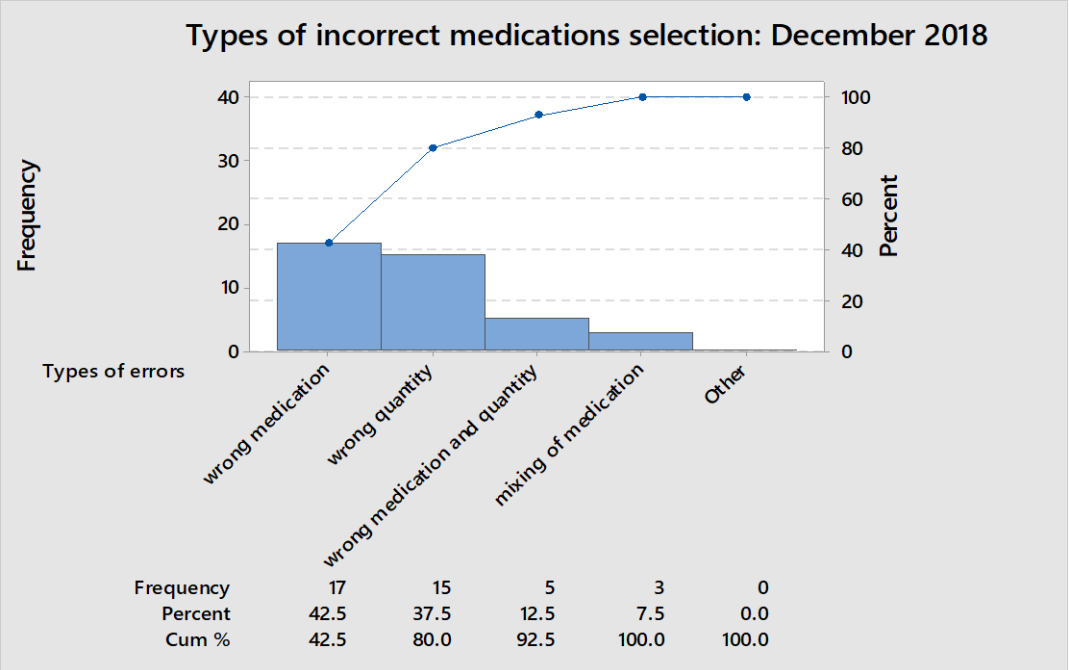
A Wilcoxon signed rank test was used to compare the number of dispensing errors pre (Mean= 5.41, SD= 1.88) and post (Mean= 3.25, SD= 1.54) LSS implementation. The results indicated that following LSS implementation, the number of dispensing errors significantly decreased (Z= -2.11, p= 0.034). Two groups (n= 12) of the number of dispensing errors before and after LSS implementation were taken with a purposive sampling for the comparison. The results indicated that the implementation of the LSS methodology caused a significant decrease in the number of dispensing errors (p= 0.034).



Stage	Number of Subgroups	Average Subgroup Size	Total Items	Number of Defectives	% Defective	PPM (DPMO)
before	25	21323	533073	154	0.03	289
after	12	21058	252699	39	0.02	154

Figure 6.11 P-chart of undetected dispensing errors before and after the improvements

Moreover, the most frequent type of incorrect selection of medication was wrong quantity reduced from 29 in April 2018 to 15 errors in December 2018, as depicted in Figure 6.12.



Frequency	17	15	5	3	0
Percent	42.5	37.5	12.5	7.5	0.0
Cum %	42.5	80.0	92.5	100.0	100.0

Figure 6.12 Types of medication selection errors after the improvements

Table 6.9 Comparison of result before and after the study

Measurement	Before	After	Percentage reduction
Process measurement			
• Incorrect medication selection	average proportion = 0.0026	average proportion = 0.0023	12
Outcome measurement			
• Dispensing errors	average proportion = 0.0003, SD= 0.0033	average proportion = 0.0002, SD=0.0028	33
Number of dispensing errors	6 errors in December 2018	3 errors in December 2019	50

Phase 5: Evaluation and Reflection

After conducting an interview with participants, four main themes emerged and summarised in Table 6.10. The details of each theme and sub-themes are explained in the following sections. The challenges and success factors of LSS implementation are presented in the next section.

Table 6.10 Themes and sub-themes emerged from the evaluation and reflection phase

Themes	Sub-themes
Change in dispensing process	-
Thoughts about DMAIC methodology and its applications in the dispensing process	Problem-solving methodology LSS can be applied in the dispensing process
Feedback from LSS training and reflection on LSS tools and techniques	Knowing more about LSS and its tools and techniques Appreciate Lean and Six Sigma tools and techniques
Knowledge gained from the project	Systems thinking

1) Change in dispensing process

The participants perceived a few changes in the dispensing process resulting from the implementation of LSS. Participants who were pharmacists felt that there was a small change in the dispensing process. Two pharmacists described it as follows:

'Creating change in the dispensing process in a large hospital required several key factors such as top management support, or hospital's policy to require change'.

'It was so difficult to change the pharmacy service. If we change these steps, it affects another step. If we want to change something that is related to technology, we have to wait for the IT department to help us'.

The pharmacy technicians expressed their positive's views about their new tasks during the selection of medications

'We were very satisfied with the new distribution of our routine jobs. It decreased a lot of tasks that I needed to do daily'.

'We thought that the new assigned tasks for each position were better than the previous jobs that we received'. (Field notes)

These findings suggest that pharmacy technicians perceived more change in the dispensing process because it decreased their workload and improved the quality of their working performance. However, in terms of the perspectives of middle managers, they did not perceive much about the change because their jobs were not involved in the medications selection process.

2) Thoughts about DMAIC methodology and its applications in the dispensing process

A. Problem-solving methodology

Participants described that the implementation of LSS could help them to understand where the problem lay in the dispensing process and within which process step. The participants' feedback included:

'DMAIC methodology helped us to understand which process step contributed to a high number of dispensing errors'.

'Every process could follow DMAIC steps. The application of LSS helped us to identify which process steps created a high number of dispensing errors. Once the root cause was identified with the data to support the decision, we could finally generate the solutions to solve the root causes of the problem'.

B. LSS can be used in the dispensing process

All participants were very convinced that LSS could be used in the dispensing process. The primary reason that participants were not applying LSS before in the pharmacy service was that they did not know about LSS. However, one of the participants indicated that some phases of the DMAIC methodology were regularly applied in the pharmacy services. Participants clarified that:

> *'We regularly applied some phases which were similar to the application of DMAIC methodology. These phases included define the problems and identify the causes of these problems. However, the solutions that we had generated never changed the dispensing process nor permanently solved the problems'.*

The researcher further reflected on this:

> *'The participants only identified the causes of the problem, the root causes of the problem still remained in the dispensing process'. (Field notes)*

However, there is a limitation regarding some potential solutions mentioned by participants:

> *'We could apply LSS to improve the dispensing process. However, we could not implement some powerful solutions due to several constraints such as resources from top management of the hospital'.*

3) Feedback from LSS training and reflection on LSS tools and techniques

A. Knowing more about LSS and its tools and techniques

All the participants identified that LSS training had resulted in more knowledge about LSS and its associated tools and techniques. They understood the structure of the DMAIC methodology. The participants were able to understand the tools that used in each phase of DMAIC methodology. LSS training increased participants' awareness of LSS principles. The following described how participants' knowledge had been improved:

> *'Previously, I understood the concept of Lean and had heard about Six Sigma. However, after the training, I learnt and understood more about LSS and its tools and techniques'.*

'I just realized LSS could assess the performance of the dispensing processes. This was an advantage of LSS that I had not known before'.

However, at the beginning of the training, some participants thought that Six Sigma was statistical. As mentioned by Antony *et al.* (2016), the 'sigma' might influence their view that Six Sigma was a statistical and measurement programme. After training, the participants clearly understood that Six Sigma was not statistical.

B. Appreciate the LSS techniques

Most of the participants felt that brainstorming and 5 Why analysis were useful techniques. These techniques were non-statistical and easy to apply by the participants. Participants explained:

'Brainstorming was the powerful technique to gather the ideas from pharmacy technicians who were familiar with their routing working'. My (head of inpatient pharmacy) views may differ from their views because I looked at problems from the top view'.

Another participant explained about 5 Why analysis:

'5 Why analysis was very useful because we could identify the root cause. It also helped us to focus on what were the root causes of the problem'.

The researcher reflected on the use of techniques:

'They had never conducted 5 why analysis before, it seems that they only solved look-alike, sound-alike drugs problem, but never tried to address other potential causes'. (Field notes)

An implication of this is the possibility that brainstorming and 5 why analysis are a simple technique that encourage participants to express their ideas without criticism by other participants in the team. The participant may feel free to express their own thoughts.

4) Knowledge gained from the project (feedback of participants' knowledge)

A. Systems thinking

Participants felt that systems thinking was important to solve the problem. DMAIC methodology was a powerful guidance for them to become a system thinker. Most of the participants explained as follows:

'The project would help me to become a systems thinker. Previously, I always wanted to jump into the solutions to solve the problem'.

'DMAIC methodology guided us to follow, and this could help us to become a system thinker'.

Moreover, the participants perceived that they could understand the whole system of the dispensing process. They were more focused on the interaction between each process step. Participants explained:

'This project helped me to look at the whole process of dispensing, and understand more the relationship between the process steps'.

The next section moves on to present the survey results to measure satisfaction of inpatients before and after the implementation of LSS. The survey results are presented in two parts: sample characteristics and overall inpatient satisfaction.

- **Inpatient satisfaction**

A. Sample characteristics

Of the 30 inpatients, most respondents were male (70 per cent). Almost half of the participants were 56-65 years old. In terms of educational background, over half of the participants (56.7 per cent) had received a bachelor's degree. One-third of the participants stayed in the hospital from one to three days. The health status of half of the participants was described as fair.

B. Overall inpatient satisfaction

Table 6.11 showed that the inpatient satisfaction with the quality of pharmacy services after LSS implementation (Mean= 4.98, SD= 0.43) was higher than before LSS implementation (Mean= 4.24, SD= 0.46). These results indicate that there was a statistically significant increase in overall inpatient satisfaction ($p < 0.05$). Interestingly, none of the respondents said they had received incorrect medications. This might be because patients usually do not know what the medication is when the nurse administers it to them and, therefore, they are unable to judge the medication they receive.

Table 6.11 Overall inpatient satisfaction

	Mean	**N**	**SD**
Before intervention	4.24	30	0.46
After intervention	4.98	30	0.43

Phase 6: Specifying lessons learnt

Three themes emerged from participants' lessons learnt from the project. These included: the role of outsider researcher, open-minded team members, and multidisciplinary team.

A. The role of the outsider researcher

Participants indicated that the outsider researcher performed an important role in motivating and driving the team to complete this project. In the pharmacy service, many significant projects need to be completed. However, the participants felt that the researcher could convince the team to join the project and make this project one of the first priority projects. The participants suggested how the researcher could drive the project:

> *'The outsider researcher was a facilitator that drove the team to complete the project. The researcher encouraged us to join the meetings during the project. If there was no outsider researcher, it would be difficult for us to implement the project by ourselves'.*
>
> *'I (pharmacist) want you to work with us for other projects'.*

The project would not have been finished and would have taken more time because participants were very busy with their main jobs every day. Therefore, a group was created in Line application (an application for instant communications on smartphones) to arrange and provide the information about the project for the participants.

B. Open-minded team members

Open-mindedness in team members and other staff in the inpatient pharmacy facilitated the implementation of LSS. The participants were able to learn from each other. Moreover, the pharmacists became open to listening to pharmacy technicians' perspectives and ideas.

> *'I have just become the head of inpatient pharmacy and my staff has been working for 20 years. I felt that when pharmacy technicians are brave enough to change, it made me brave enough to change as well'.*

The researcher reflected to this situation as follow:

'I realised that the pharmacist always solves the problem without involving pharmacy technicians in a team. The project gave them a great opportunity to work together and learn from each other'. (Field notes)

C. Multidisciplinary team

The majority of participants reported that an effective multidisciplinary team was a key factor in the implementation of the potential solution. They suggested that the team should include a group of healthcare staff from different disciplines and levels in the organization. Moreover, participants demonstrated that having two senior pharmacy technicians was a key factor leading to the success of the project. These two senior pharmacy technicians had been working in the pharmacy service for over 10 years and had gained a lot of experience.

'Some potential solutions we could not implement by ourselves. The staff from the information technology (IT) department should be involved in the team'.

'It took time to implement some solutions because we had to wait from the IT department. In this project, we could only implement the solutions that were not related to the technology'.

6.3 Challenges of LSS implementation in Hospital B

Resistance to change was a main theme emerging from the interviews with participants. The following section explains how participants encountered and overcame with challenge.

6.3.1 Resistance to change

Resistance from pharmacy technicians was the major challenge encountered by the team. It was difficult to convince the pharmacy technicians to make changes in their routine tasks. There were familiar with their regular tasks and resisted change to their routine work. Participants explained:

'Pharmacy technicians were familiar with their regular tasks. They wondered what was going to happen if we changed their routine working'.

However, participants suggested that the outsider researcher could persuade them to change and ensure the outcome of LSS employment.

'It is a Thai culture that people are afraid of change. However, the support from the outsider researcher could convince the pharmacy technicians to change their routine working'.

The participants further suggested that it is important that all staff in the inpatient pharmacy understand LSS methodology, so that they could prepare themselves for change.

6.4 Critical success factors for LSS implementation in Hospital B

Two themes emerged: understanding of LSS methodology and top management support as the key factors for successful implementation of LSS in Hospital B. The following sections explain the detail of each theme.

6.4.1 Understanding of LSS methodology

Participants mentioned that an understanding of LSS and its benefits played an important role in driving the project successfully. Moreover, at the beginning of the project, awareness of the importance of LSS motivated participants to perceive how LSS could improve their routine working. The following comments showed the importance of team members' understanding of LSS methodology:

'All participants understand the importance of LSS was a key factor that made the project a success'.

'Understanding the LSS methodology helped us to understand the different tools for use in each phase of DMAIC methodology'.

However, the Head of Inpatient Pharmacy suggested that not only should participants understand and receive LSS training, but also all staff in the inpatient pharmacy.

'If only I understood LSS and other staff did not know, LSS could not be useful. It was important to introduce LSS to all staff. Therefore, they could understand that the implementation of LSS could reduce their workload and give them a better working life. If they did not understand LSS at the beginning, LSS was just a theory but could not be implemented in a practical situation'.

6.4.2 Top management support

The support and commitment from top management of the hospital were considered by participants as another key success factor, although, top management had not been

involved in the project. The pharmacists suggested several points regarding the support from top management which could make the project more successful:

> *'The top management should provide resources such as budget and support the project team'.*
>
> *'The support from top management could facilitate the implementation of LSS'.*

Interestingly, only pharmacists mentioned that top management support is a key success factor of the project. The pharmacy technicians seemed to focus on their new routine works.

6.5 Reflection on the research process from the initial stage

At the beginning of the project, top management of the hospital thought that I could not help to improve the dispensing process. However, every hospital needs process improvement. When I entered the inpatient pharmacy, the environment was a well-organised workplace and cleanliness was paramount.

It was very challenging to introduce LSS methodology to the healthcare environment. Some of the participants had some knowledge of Lean, but none of the participants had any knowledge of Six Sigma. In order to overcome this difficulty, during LSS training, I provided an opportunity for all participants to ask questions and spent time clarifying each question.

During each phase of the action research methodology, one of the greatest challenges faced was participants' time commitment. It was difficult to arrange a meeting to conduct a focus group or interview with participants due to their limited time. I had to arrange the meeting myself and motivate the team during the project. In some months during the project, I could not arrange the meeting because all participants were very busy on their own jobs. Moreover, in the taking action phase, it was quite difficult to implement some potential solutions due to time and financial limitations. For example, some solutions such as barcode could not be implemented because the team had to wait for assistance from the IT staff and hospital's policy.

At the end of the project, I was happy that the team could implement the solutions to improve and create change in the dispensing process. Even LSS cannot reduce a high number of dispensing errors, but at least there is an improvement in the dispensing process.

6.6 Key lessons learnt

The key lessons identified from the implementation of LSS through the action research methodology were as follows.

- The smooth running of the project requires the support from top management throughout the project. This project could fail without a good relationship between the researcher and participants.
- Everyone in the inpatient pharmacy should understand the importance of LSS and how LSS could be applied to improve their existing process. Not only participants should receive LSS training, but also all the staff in the department should have a fundamental knowledge of LSS and its tools and techniques.
- LSS is suitable for complex processes.
- Following DMAIC steps is a key success factor. The researcher realised that during the project, participants tried to think ahead of the solutions in order to get a quick result (George *et al*., 2005).
- Gemba walk is a powerful tool to understand and identify the problems in the process. It provides a great opportunity to see what is happening and how staff are performing in the dispensing process.
- A positive aspect of the pharmacy technicians was their willingness to openly discuss the problems with the Head of Inpatient Pharmacy and the researcher.
- Participants' having time is one of the major factors that drives the project and ensures its success.
- Bringing about change in the healthcare sector requires the commitment of time on the part of the participants. To manage change in healthcare, leaders should learn how to manage change instead of change managing them (Al-abri, 2007).

6.7 Chapter summary

In summary, the findings show that collaboration between the researcher and participants can improve the dispensing process. The problem contributing to the occurrence of dispensing errors was identified and addressed through the key phases of the action research methodology. The successful implementation of LSS resulted in improvements in the performance of an existing dispensing process. The LSS project has shown a reduction in dispensing errors in the inpatient pharmacy. The average proportion of undetected dispensing errors reduced from 0.003 to 0.002, representing a 33 per cent reduction. Importantly, the project has improved patient safety by reducing dispensing

errors. It has created better communication between pharmacists and pharmacy technicians and increased patient satisfaction. The participants also noted that resistance to change was very challenging. Based on the researcher's own reflections, insufficient resources and knowledge of LSS were also the barriers when applying LSS in the inpatient pharmacy. However, the study highlights that the understanding of LSS methodology and top management support were key success factors of LSS implementation in this project.

CHAPTER 7 – LEAN SIX SIGMA ROADMAP TO REDUCE MEDICATION ERRORS

7.1 Introduction

The chapter presents an LSS roadmap to guide healthcare practitioners in the implementation of LSS along with a customized LSS tool kit for reducing medication errors. The first section critically reviewed several frameworks/roadmaps of Lean, Six Sigma and LSS which have been proposed in healthcare sector from the existing literatures. The next section proposes an LSS roadmap to be followed by healthcare practitioners for the implementation of LSS to reduce medication errors and enhance sustainability of LSS across their organizations. This roadmap includes three phases: **Phase 1** cultural readiness for LSS employment in reducing medication errors; **Phase 2** preparation, initialization, implementation, and **Phase 3** sustainability.

7.2 A roadmap of LSS in the reduction of medication errors

As identified in Chapter 2, the review revealed that the current literature has not provided a Lean, Six Sigma or LSS roadmap for healthcare practitioners that they are able to follow to reduce medication errors. Therefore, in order to bridge this gap and answer Research Question 4 *"How can an LSS implementation and sustainability roadmap be developed to guide healthcare practitioners in the reduction of medication errors?"* one such roadmap was developed in order to reduce medication errors in hospitals.

7.2.1 The development of an LSS implementation and sustainability roadmap to reduce medication errors

Due to the limitations of the LSS framework/roadmap and its characteristics in healthcare sectors, an LSS roadmap was developed based on the LSS roadmap for SMEs proposed by and Kumar *et al.* (2011), Antony *et al.* (2016), and Timans *et al.* (2016), the key articles on Lean readiness in the healthcare context such as Al-Balushi *et al.* (2014) and Alnajem *et al.* (2019) and the experiences of the researcher gained from undertaking the action research in two hospitals.

Figure 7.1 presents the conceptual LSS roadmap which includes three phases: **Phase 1** Cultural Readiness, **Phase 2** Preparation, Initialisation and Implementation, and **Phase 3** Sustainability. This can help healthcare practitioners to apply LSS in a sequence and systematically (Kumar *et al*., 2011) to reduce medication errors. Following the

presentation, the conceptual LSS roadmap was verified by a number of LSS experts (e.g. Master Black Belts and Black Belts) and a healthcare practitioner to ensure that it could be applied successfully in the hospital.

The criteria for choosing the LSS experts included that they had: 1) to complete at least five Black Belt or Green Belt projects; 2) experience in coaching Black Belts with successful project completion; and 3) leadership and change management skills (Watson, 2003). The number of experts was identified based on Almutairi *et al*'s study where they used 15 experts to validate the roadmap. However, in this study, the data reached the saturation point when the number of experts was 11. Most of the LSS experts were contacted by the researcher via LinkedIn and the details of the LSS roadmap were explained to them. The experts and the healthcare practitioner were asked to provide comments or suggestions on the conceptual LSS roadmap (Alnajem *et al.* 2019). Then, the researcher conducted an online interview to obtain comments from them. Table 7.1 summarises the background and comments of LSS experts and the healthcare practitioner.

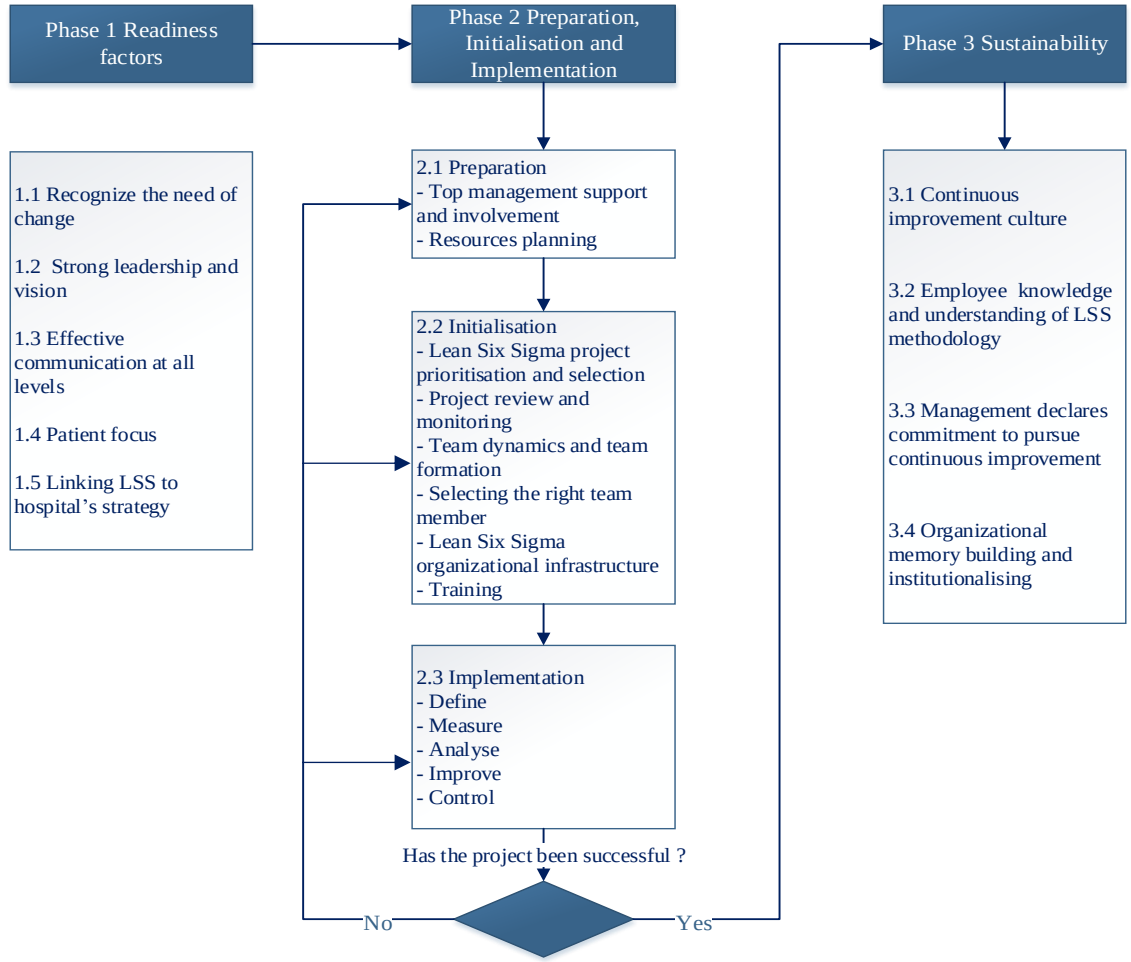


Figure 7.1 A conceptual LSS roadmap

Table 7.1 Background and comments of LSS experts and the healthcare practitioner

Sr. no.	Six Sigma Belt	Positions	LSS experience (years)	Comments
1	Master Black Belt	The CEO of The Institute of Six Sigma professionals, UK	16	Add fours factors under phase 3 (sustainability) which includes: investors in people (IIP standard), future trend and development, succession training and organization review and strategy review Instead of saying management declares commitment to pursue continuous improvement, IIP standard would be used to measure the management commitment.
2	Master Black Belt	General Manager of Green Sport (Thailand) Co Ltd. Coaching healthcare practitioners to implement LSS in public hospitals (Volunteer)	16	The overall roadmap is good. The timeframe should be added to the roadmap. Normally, it takes 2-3 years for LSS transformation.
3	Master Black Belt	Plant Director of Ansell (Thailand) Ltd.	8	The sequences of the road map are good. It is important to ensure that the top leader trusts that LSS is the right tool for improvement and transformation.
4	Master Black Belt	Lean Six Sigma Master Black Belt at Michelin, Thailand	15	Phase 2 focuses more on a top-down approach. There is no bottom-up approach because lean focuses on bottom-up, change mind-set and change a culture.
5	Master Black Belt	Head of Operational Excellence, Asset World Corporation, Thailand	20	Project champion training could be added into phase 2
6	Master Black Belt	Lean Six Sigma Consultant / Minitab trainer	15	The sequence of the road map is good. The timeframe should be included in the roadmap.

7	Black Belt	The Director of Bespoke Clinical Care Ltd, UK	6	LSS is an ongoing improvement process so that future, trend, and development is important in terms of where LSS will be in the future. The key step to sustain LSS is showing people what is the advantage of doing LSS and then breaking the culture.
8	Black Belt in Healthcare	Head of Strategic Supply Chain Management	6	The overall roadmap is good. Staff buy-in is very important for LSS sustainability. To sustain LSS in hospitals, the hospitals could create an event every year about process improvement by using LSS.
9	Black Belt	LSS Black Belt at 3M Thailand Ltd.	6	The overall roadmap is good. Project scope is important and should be clearly identified.
10	Black Belt	Head of Service Delivery, Krungthai-AXA Life Insurance PCL.	13	The sequences of the three phases are reasonable. However, creating an LSS culture should be moved to phase 1.
11	-	Clinician in the UK hospital	6	The sequence of the roadmap is good. To sustain LSS in hospitals for a period of time, LSS should become a part of staff's daily life. Start with a small simple thing and simple that people can understand. Show successful stories and how LSS can make their life easier and then staff will engage because they can see how LSS benefits them.

Then the comments from LSS experts and the healthcare practitioner lead to the revised LSS roadmap, as shown in Figure 7.2. Phases 1 and 2 of the revised version mostly contain the same elements as the conceptual LSS roadmap. The major modification has been made in phase 3. Three factors: future and trend of LSS, succession planning, and organization review and strategy review have been added into this phase. The factor 'management declares commitment to pursue continuous improvement' has been replaced by an investor in people (IIP). In phase 2, training has been replaced by 'project champion training and LSS training'. Moreover, the timeframe of each phase has been

added to the initial LSS roadmap. This timeframe has been benchmarked with the timeframe provided by the Master Black Belt.

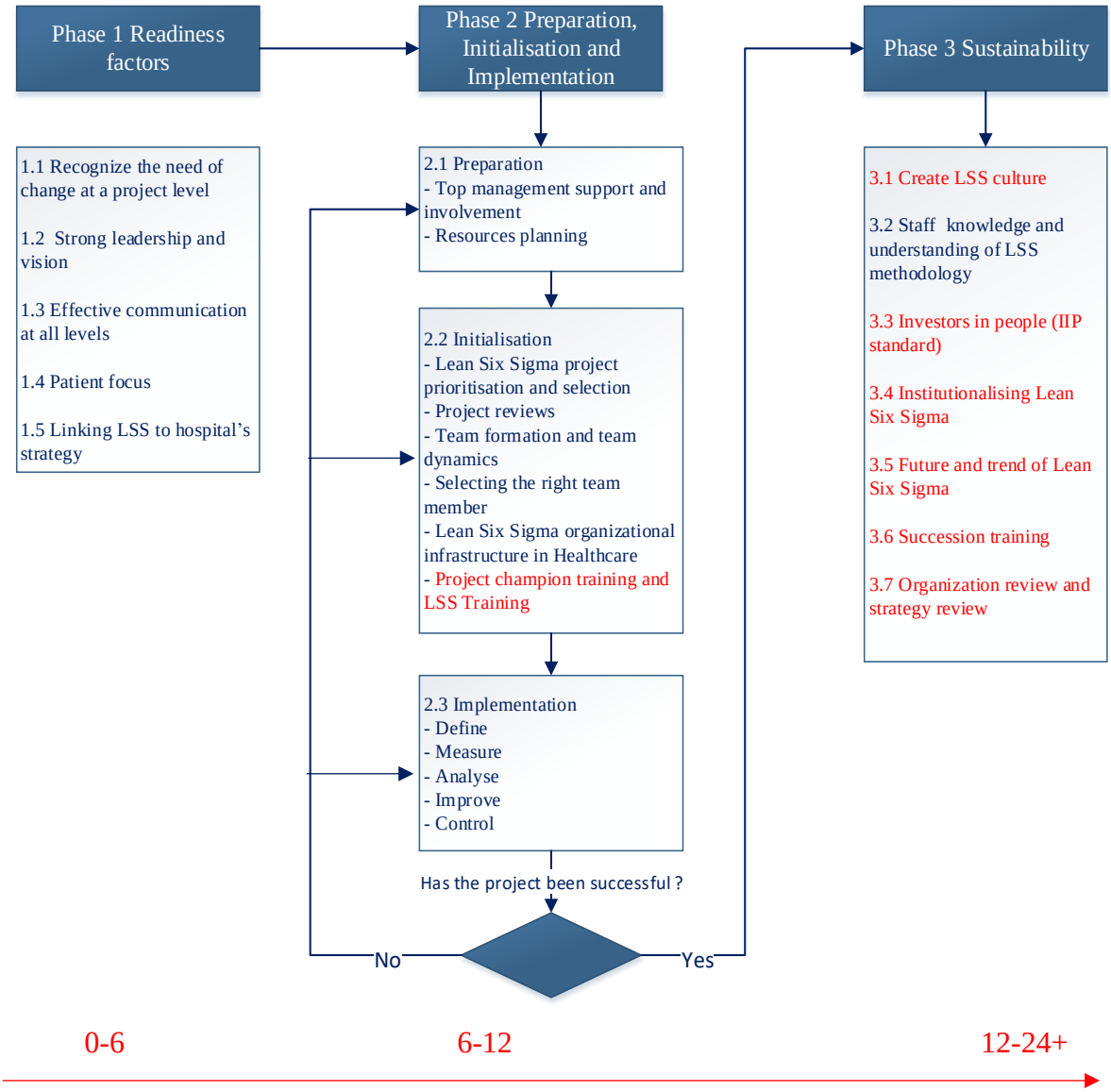


Figure 7.2 The revised LSS roadmap

Figure 7.3 presents a final version of the LSS implementation and sustainability roadmap. The following section explains the three phases of LSS implementation and sustainability roadmap for reducing medication errors: **Phase 1:** Readiness factors for the implementation of LSS in the reduction of medication errors; **Phase 2:** Preparation, Initialisation, and Implementation; and **Phase 3:** Sustainability. These three phases were developed based on the existing literature including Kumar *et al.* (2011), Al-Balushi *et al.* (2014), Antony *et al.* (2016), Timans *et al.* (2016), and Alnajem *et al.* (2019).

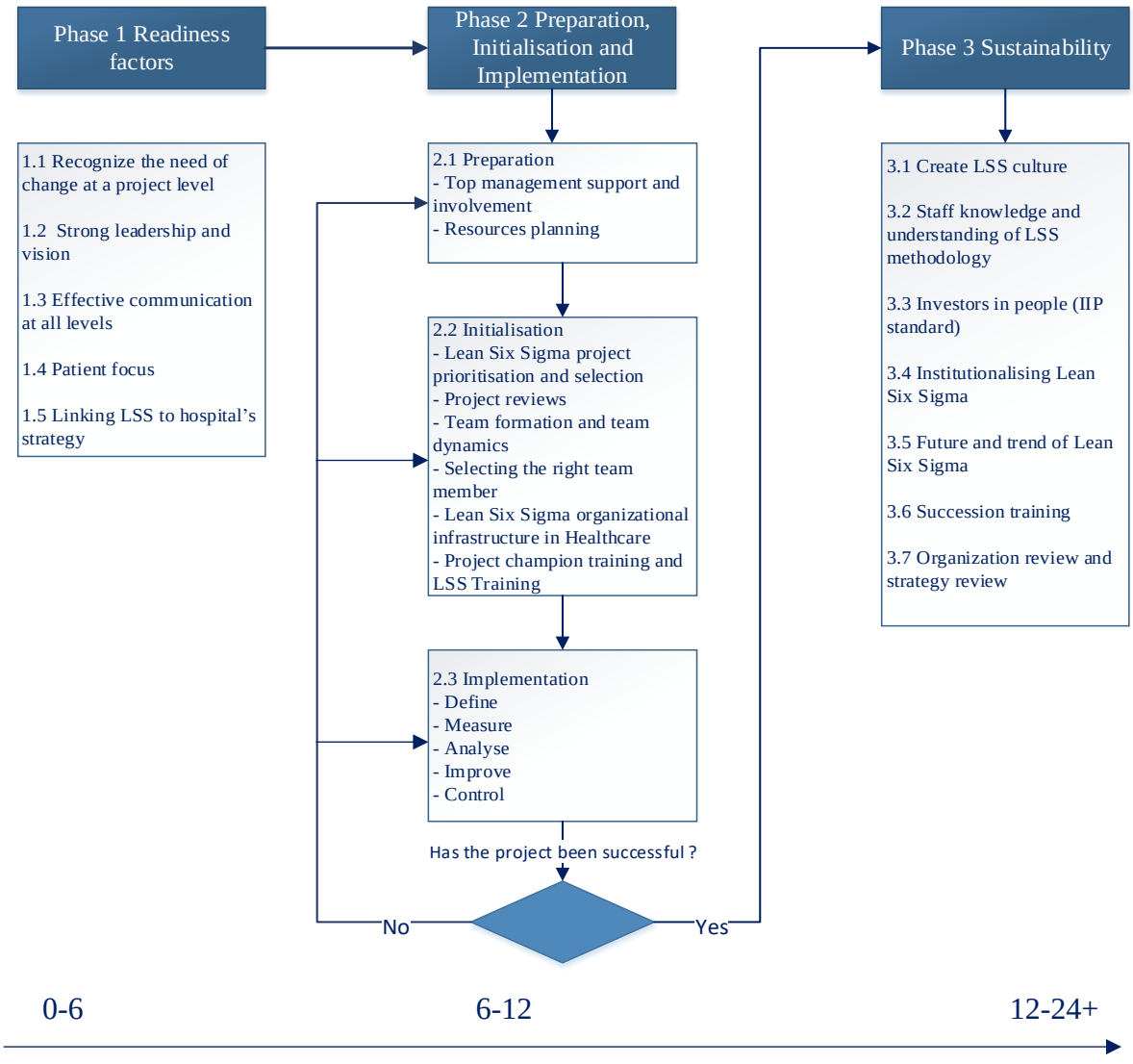


Figure 7.3 The final version of LSS roadmap

7.2.2 Phase 1: Readiness factors for the implementation of LSS in the reduction of medication errors

This phase aims to assess the readiness of the hospitals before commencing on the execution of LSS projects (Kumar *et al.*, 2011). Readiness factors are an important element that facilitates the successful implementation of LSS before the hospitals invest some resources such as finances, time, and manpower (Antony, 2014). These readiness factors are important to assess whether the department or a business function for its readiness to implement LSS in improving the medication process. If the department is not ready for LSS deployment, it could lead to the failure of the next phase (i.e., implementation), frustration among staff and resistance from the staff (Antony, 2014; Antony *et al.*, 2016). The following readiness factors have been identified in order to commence the LSS initiative.

A. Recognize the need for change at a project level

The implementation of LSS can lead to alterations in the current medication process, systems or staff roles in a department (e.g. inpatient/outpatient pharmacy or wards) so that resistance to change may occur. For example, pharmacy technicians do not want to change from their current roles or follow a new process. Prior to embarking on an LSS project, it may be difficult to make changes in the existing medication process due to internal resistance from staff. Therefore, all staff in the pharmacy service or other departments involved in the medication process should be notified in advance that LSS will be implemented to reduce medication errors, and this implementation may affect their routine working practices.

Middle management could develop a presentation regarding the benefits of LSS and how LSS could be applied to improve their current jobs (Kotter and Schlesinger, 2013). Moreover, it is important to explain in detail the reasons for a change to establish a sense of urgency (Kotter, 2007). For example, the Head of Pharmacy Department may explain the need for change to the staff because the current errors in the dispensing process contribute to patient dissatisfaction.

A successful transformation of change at a project level requires clear communication, vision, and motivation from the leader to overcome resistance to change (Mustapha *et al*., 2019). The leader should communicate with staff about the challenges that everyone might face during the implementation of LSS (Antony, 2014). The following variables should be considered in this factor.

- Staff who are involved in the medication process understand the need for change through clear communication, vision and motivation from the leader.
- The leaders should recognize the need for a major change in the medication process.
- A clear vision should exist and this vision should be communicated to clarify the direction in which the department needs to move (Kotter, 2007).
- Clear communication channels are required within the department about the need for change (Schweikhart and Dembe, 2009).

B. Strong leadership and vision

Transformational leadership is essential to the successful implementation of LSS in the hospital. Transformation leadership is a leadership style in which leaders motivate people and encourage them to collaborate to achieve LSS project goals and create a vision to make changes in the current culture of the hospitals (Laureani and Antony, 2019). When LSS has been implemented in a pharmacy service or other departments in the hospitals to improve the medication process, it may change the routine working of the staff. The leaders (e.g. director of the hospital, CEO) should be able to motivate and to enable staff to change their current working routine and encourage a mindset in order to achieve the desired results (Antony *et al*., 2007; Snee, 2010; Antony, 2014). However, management is responsible for the allocation of the necessary resources for LSS implementation.

Leadership can change the attitude of the healthcare staff, their readiness for improvement within the medication process through exchanging of information and ideas (Tsironis and Psychogios, 2016). Leadership is required to sustain improvement (Snee, 2010) and should cut across every phase of the LSS roadmap. It is important to put the effective leadership in place to ensure the success of LSS deployment, coupled with the top talent in the organization involved in LSS, providing them with the right project management tools and methodology, and making them financially accountable for the success of the initiative (Trakulsunti and Antony, 2018). The following variables are important in relation to this factor, as adapted from Antony *et al.* (2007), Antony (2014), and Trakulsunti and Antony (2018).

- Identify a clear direction for and guidance on the implementation of LSS
- Top leaders should be able to describe why LSS is needed.
- Communicate the vision to staff at different levels to gain organizational commitment and create an LSS culture by getting staff buy-in.
- Leaders should provide support, direction, and encouragement to staff for a successful implementation of LSS.
- Leaders are able to address all types of resistance to change (technical, political, etc.).
- Leaders should communicate the improvements resulting from the LSS project through a range of media such as newsletters, social media, and forums throughout the hospital.
- Recognizing and rewarding staff who are involved in the improvements in the medication process is important (Kotter, 2007). The recognition and rewards that

staff can receive from the organization can be financial (e.g. a bonus) and non-financial (e.g. LSS certification ceremony, promotions) (Hoerl, 2001).

C. Effective communication at all levels

Effective communication means that the information is successfully delivered, received and understood between two or more people without any distractions (Sibiya, 2018). The communication is effective at all level when the information is shared from top-down and bottom-up, to work towards a project goal (Antony and Banuelas, 2002). The implementation of LSS requires effective communication channels within the hospital or department to minimize the resistance to change (Schweikhart and Dembe, 2009; Antony and Kumar, 2012).

Effective communication channels at all levels for the people who are directly involved in the project or affected by the LSS implementation is crucial to help the project run smoothly and successfully (Antony and Banuelas, 2002; Antony *et al*., 2007; Salah *et al*., 2010). Staff who are involved in the medication process should understand the importance of LSS and how LSS could be applied to improve the current medication process (Antony *et al*., 2019b). The following variables should be considered under this readiness factor, as adapted from Antony and Banuelas (2002), Shitu *et al*., (2018), and Alnajem *et al*., (2019):

- Effective communication between healthcare practitioners and departments is crucial.
- Effective communication entails top-down and bottom-up communication (Antony and Banuelas, 2002).
- Effective sharing of information between doctors, nurses, pharmacists, and patients is needed.
- Attention should be paid to ensure a correct exchange of information (Shitu *et al*., 2018).
- Be clear and specific when explaining important information

D. Patient focus

A primary goal of the healthcare service is to protect patients from harm, improve patient safety and provide a high-quality service. An LSS project should begin with the understanding of patients' needs and identification of the factors that are critical to the patient (Antony and Banuelas, 2002; Burgess and Radnor, 2013 Alnajem *et al*., 2019). It would be difficult to initiate an LSS project without a thorough understanding of patient requirements (Alnajem *et al*., 2019). Patients can provide the information to the department regarding their expectations of the service (Raghunath and Jayathirtha, 2013). For example, patients expect to receive the correct medication at the right dose and concentration and at the appropriate time during their treatment process. The department should be ready to change the culture, improve the medication process or systems in order to meet the patients' requirements.

In healthcare, the voice of the patient (VOP) can be used to capture the patients' needs and expectations of today and tomorrow. The needs of patients can be identified by two types of data: reactive data (e.g. patient complaints, compliments, and feedback for improvement) and proactive data (e.g. interviews, surveys, and focus groups) (Breslin *et al*., 2014; Antony *et al*., 2016). The set of variables under this readiness factor, adapted from Antony (2014) and Antony *et al*., (2016), are listed as follows.

- Linking patient focus to the hospital's strategy and projects (Antony *et al*., 2016).
- Understanding patient's requirements and performing only those activities that serve their requirements.
- Staff accepting and understanding that patients are not the only customers of the hospital; internal customers such as doctors, nurses, and pharmacists are also equally important as they serve the external customers (i.e., patients) (Antony, 2014).

E. Linking LSS to hospital's strategy

Linking LSS to the organization' strategy has been widely emphasized as a key success factor for LSS deployment (Alhuraish *et al*., 2017). Linking the LSS project objectives to hospital strategic goals can create a long term change in the hospitals (Dick *et al*., 2006; Psychogios *et al*., 2012; Al-Balushi *et al*., 2014). The staff can understand the nature, the purpose, and benefits of their routine work (Al-Balushi *et al.*, 2014). Without a clear

vision and purpose of the initiative, the staff may not realize the importance of LSS. The staff are more willing to accept change in their roles when LSS deployment is clearly communicated as a long term policy within the hospital's strategy (Bateman and Rich, 2003). The following variables adapted from Antony (2014) are important under this readiness factor.

- Ensure that the LSS project is aligned with the hospital's strategy.
- Determine the success of the project by identifying measurement factors such as hospitalization costs, number of medication errors and staff and patient satisfaction.
- Top management communicates the strategy and the purpose of the initiative across the hospital (Antony, 2014). Moreover, senior management should be involved in making sure that projects have an alignment with the strategic objectives of the hospital.

To ensure that the department is ready to embark on LSS and cultural transformation, the degree of cultural readiness should be assessed. Research has shown that each readiness factor may be attributed to a set of variables and it is important to understand how ready a hospital is with regards to such variables. Kumar *et al.* (2011) use the term 'percept' in relation to measuring the readiness factors. Thus, they adopted a five-point Likert scale for each variable ranging from (1) percept not implemented at all; (2) percept slightly implemented; (3) percept moderately implemented; (4) good implementation of percept; and (5) percept fully implemented (Kumar *et al*., 2011). The hospital can continue to the next phase, if each variable gets a score of 3 (Kumar *et al*., 2011).

7.2.3 Phase 2: Preparation, initialisation, and implementation

Preparation

This phase helps the hospital to evaluate the commitment from top management to make changes in the medication process and allocates resources to the LSS project team. Top management support and involvement, as well as resource planning are important elements in this phase, each of which is explained below.

A. Top management support and involvement

The application of LSS in the hospital is difficult because most of the healthcare staff are unfamiliar with LSS methodology. Hospital managers should understand the concepts,

benefits of LSS and how to implement LSS (Raghunath and Jayathirtha, 2013). LSS deployment should start with a two-day overview of the methodology in order to gain top management buy-in (Antony, 2014; Trakulsunti *et al*., 2018). Once top management is convinced of the need for LSS implementation, they can communicate with staff as to how their involvement contributes to the success of LSS and achieves the hospital's strategy. All levels of managers should provide assistance, the necessary resources (e.g. time, budget and human) for executing the LSS projects, training and ownership to solve problems (Antony and Banuelas, 2002; Habidin and Yusof, 2013; Antony, 2014).

B. Resources planning

The allocation of resources such as time and budget for the deployment of LSS is an important factor before the execution of an LSS project (Antony, 2014). The major challenge of LSS implementation to reduce medication errors in hospitals is the allocation of time. The success of the LSS project depends primarily on the allocation of time to team members. It is important to ensure that the team members provide sufficient time to engage in LSS projects (Antony, 2014). Prior to the project, the project team should develop an implementation plan to ensure that the team can complete it on time and the project champion should monitor the progress of the project. Doing an LSS project in the hospital setting, it might take more time to complete the project depending on how well the team members have been trained on the methodology and the associated tools of LSS. In addition, a necessary software programme such as Minitab should be made available to support the project team during the implementation of LSS.

Initialisation

This phase helps the hospitals to select the right LSS project and the right people to work in the team. Once the LSS project has been identified, the formation of the project team is an important aspect to be considered by the hospitals. Afterwards, the selected team members should receive LSS training to drive the project successfully.

A. LSS project prioritisation and selection

In healthcare, project prioritisation and selection is critical to the success of the project (Antony *et al*., 2007; Desai *et al*., 2012). Selection of the right project can help the management and staff to realise the true benefits of LSS (Bhat *et al*., 2016). The project selection in the hospital should focus on the voice of the patient and identify the CTQ

characteristics which are linked to the voice of the patient. Before implementing LSS in the pharmacy service or other departments in the hospital, it is important to choose a project that is patient-oriented and financially beneficial. For this research, selection guidelines identified by Antony *et al.* (2007) were adopted. These are:

- The project should be linked to the hospital's strategy or policies, and patient care problems.
- The project should have an impact on both internal customers and patients' needs and expectations.
- The project should be looking into a chronic problem where previous attempts to tackle it have not been successful.
- Project goals should be clear, specific and measurable such as the number of dispensing errors, waiting time and patient satisfaction.
- During the project selection process, the project team should identify the criteria to select the projects (Sharma and Chetiya, 2010). The following criteria should be considered, including: patient satisfaction, financial benefits, top management support, duration of the project, data availability, risks involved, and resources required for the project.

B. Project reviews

A project review is an important activity to ensure a successful implementation of LSS and completion on time. Antony *et al.* (2016) suggested that the review could be performed by an LSS project champion along with other LSS experts (e.g. Green Belts or Black Belts). The champion reviews the overall progress of the project to ensure that the project meets the schedule, project objectives, goal, budget and aligns with the hospital's strategy. The reviews should be carried out at the end of each phase of the DMAIC methodology to understand if there any bottlenecks with regards to progress of the project. The followings questions could be included during the review by the LSS project champion:

- Is the project executed as planned and scheduled?
- Is the overall progress made in each phase of DMAIC methodology acceptable?
- Is there a problem regarding budget and resources which could potentially hinder the progress of the project?

C. Team formation and team dynamics

The formation of the LSS project team is an essential component in LSS implementation (Antony *et al*., 2016). An LSS project requires a multidisciplinary team to facilitate its deployment. The team should include all staff who are involved in the medication process which consists of doctors, pharmacists, pharmacy technicians, nurses, IT staff and other stakeholders. The Head of the Pharmacy Department or consultants should lead the project. Moreover, it is important to choose a team leader and members who have experienced in the medication process and be confident to express their ideas or opinions with other members. They should also have a good understanding of the DMAIC problem-solving methodology and the associated tools.

Team dynamics can be defined as 'the motivating and driving forces that propel a team towards its goal or mission' (Eckes, 2002, p.3). Poor team dynamics, such as lack of motivation of the team members, could lead to the failure of LSS implementation (Antony *et al*., 2019c). Several approaches should be considered to improve team dynamics such as identifying a leader, defining roles and responsibility of project team members and dealing with resistance to change at a project level. The hospitals should have internal or external project champions to monitor and review the progress of the LSS project and deal with resistance to change at the project level.

D. Selecting the right team member

Identifying the appropriate composition of team members to execute the LSS project is an important factor leading to the success of LSS implementation (Trakulsunti *et al*., 2018). The LSS project should include staff who are motivated intrinsically to implement LSS to minimize medication errors. Team members should be selected based on criteria: who has the complementary skills needed, familiarity with the process, can generate the solutions, and will be involved in LSS implementation (Hoerl and Snee, 2002). Moreover, The team should include a diversity of team member skills and expertise such as change management, problem-solving, project management and analytical skills (Raghunath and Jayathirtha, 2013; Antony, 2014). The team members not only should have experience regarding the medication process, but should also understand LSS methodology and be able to apply appropriate tools and techniques in each phase of the methodology.

E. Lean Six Sigma organizational infrastructure in healthcare

The LSS infrastructure plays an important role in the implementation of LSS in any organizations (Antony *et al*., 2016). Generally, the roles within the LSS project include: the project Champion, Master Black Belts, Black Belts, Green Belts, and Yellow Belts. The Champion is responsible for supporting the team when they need resources, periodically reviewing the project progression and removing all obstacles during the project execution (Snee, 2001; Mahanti and Antony, 2005; Gijo *et al.*, 2013). Master Black Belt has the highest level of LSS expert which involves in mentoring and coaching, followed by Black Belts and Green Belts (Stankalla *et al*., 2019).

The team leader is trained as the Black Belt or Green Belt who works as a full-time Six Sigma expert and has responsibility for leading the team to complete the project on time and communicate with the champion regarding the status of the project (Coronado and Antony, 2002; Gijo *et al*., 2013). Team members are trained as Green Belts or Yellow Belts to execute the LSS project and work under the guidance of Black Belts and collect the data (van den Heuvel *et al*., 2006; Taner *et al*., 2007).

Figure 7.4 shows the LSS infrastructure in the hospital which was developed based on the experiences of the researcher gained from undertaking the action research in two hospitals in Thailand. The Champion could be a director of the hospital. The project leader could be the Head of Pharmacy Department who is trained as a Black Belt or Green Belt or by hiring a Black Belt. However, when the Green Belt becomes the leader, the time constraint is a significant factor that affects the project timelines (Eckes, 2002; Laux *et al*., 2015). This is because they have their own regular work to perform and may lack motivation to lead the LSS project. It is suggested that the project leader should be the Black Belt who leads the LSS project in the hospitals to reduce medication errors. If the LSS experts do not exist in the healthcare organizations, the hospitals may send staff to be trained or employ an experienced external Black Belt or Master Black Belt (Ganti and Ganti, 2004, van den Heuvel *et al*., 2005). For example, in the Red Cross Hospital, the Green Belts faced in closing their project and, therefore, a Master Black Belt was appointed to support the Green Belts (van den Heuvel *et al*., 2006). The Master Black Belt also provided the necessary training of the Green Belts and ensured that they completed one project before initiating another project (van den Heuvel *et al*., 2006). Finally, the team members should receive at least Yellow Belt training and have experience with regard to the medication process. The team members should ideally include pharmacist(s), nurse(s), doctor(s), pharmacy technician(s) and staff from the information technology department.

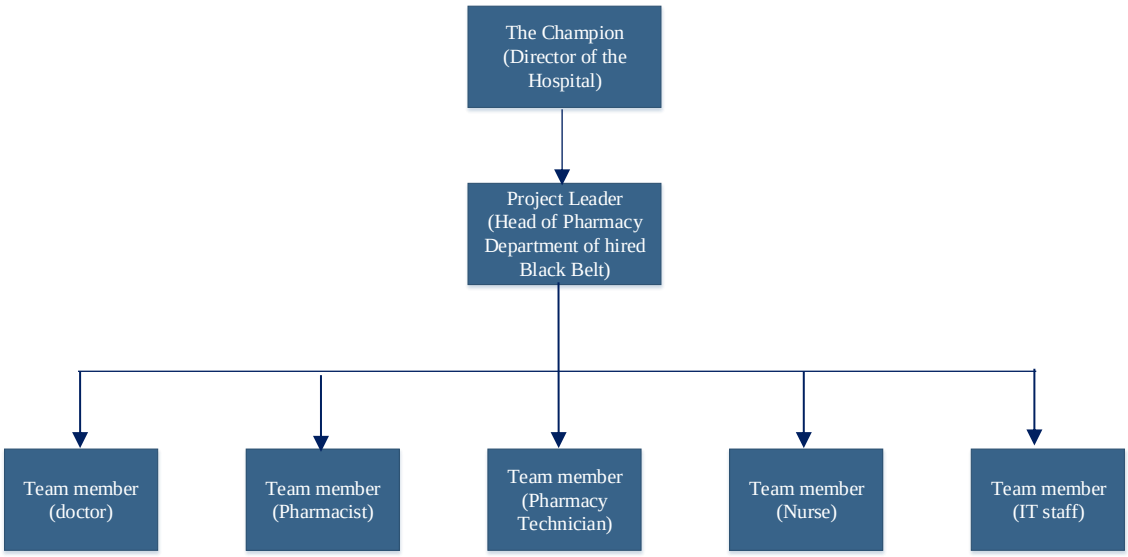


Figure 7.4 LSS infrastructure in the hospital

F. Project champion training and LSS training

Training is a significant factor leading to the success of LSS projects. It is important to provide training to all people who are involved in the implementation of LSS in the organization (de Koning *et al*., 2006). For example, the champions should receive the training to understand what types of project to select as an LSS project, who to select as team members, and how to monitor the progress of projects (Antony *et al*., 2018a). The duration of project champion training is one to two days based on the stages of LSS evolution in the organization (Antony *et al*., 2018a).

LSS project team members should receive LSS training provided by external or internal LSS facilitators who have the skills and experience in LSS implementation. The duration of LSS training is six to ten days (Pande *et al*., 2000). Figure 7.5 summarises the details of an LSS training course in healthcare. The training covers the information that helps the LSS project to run smoothly such as data-based decision making emphasizing the importance of data collection and analysis for process improvement (Antony *et al*., 2016).

However, in order to minimize the budget and resources, the hospital may select one or two staff to receive Six Sigma Black Belt training (Kumar *et al*., 2011). Then, the hospital may employ a train-the-trainer approach which means that the Black Belts can train the Green Belts and the Yellow Belts. The LSS project is likely to be more successful if all staff in the hospital who relate to the improvement of the medication process understand the fundamentals of LSS via a one-day White Belt course.

Overview

The Lean Six Sigma training is designed for anyone in healthcare institutions who wishes to understand the fundamentals of Lean Six Sigma methodology for solving problems in the context of healthcare organizations, such as to improve patient flow, reduce medication errors and reduce waiting time. The training provides the fundamentals of the Lean Six Sigma principles, tools and techniques of Lean Six Sigma. Some successful Lean Six Sigma projects are also presented to the participants. By the end of the training, the participants are able to execute Lean Six Sigma improvement projects.

Key Topics

1. The principle of Lean thinking and forms of waste in the healthcare process
2. Introduction to Six Sigma and Lean Six Sigma
3. The basis of Lean Six Sigma tools and techniques (e.g. control chart, run chart,5S, VSM, FMEA, Poka-yoke)
4. Critical success factors and the benefits and challenges of LSS implementation in the reduction of medication errors
5. Fundamentals of Minitab software
6. Lean Six Sigma case studies in different healthcare sectors

Learning Outcomes

1. The delegates are able to apply DMAIC methodology for tacking problems in healthcare organizations.
2. Develop an understanding in the use of an appropriate Lean Six Sigma toolkit in each phase of DMAIC methodology.
3. Understand how to implement Lean Six Sigma project in healthcare organizations and the challenges that may be faced during the project execution.
4. Evaluate the critical factors that are required for the successful implementation of Lean Six Sigma in healthcare organizations.

Figure 7.5 Lean Six Sigma training in the healthcare curriculum

Implementation

The project team can follow the DMAIC methodology and use a number of LSS tools and techniques in each phase of the methodology. The following section explains each phase of DMAIC methodology, and the tools and techniques that could be used in each phase of the methodology.

1) Define Phase

The first phase of LSS methodology aims to identify the scope and goals of the project and problems associated with the medication process (Gijo *et al*., 2013). The project team should develop a project charter including all details of the project: scope; team members and problem statement. For example, the goal statement of the project is "to reduce medication errors in an outpatient pharmacy by 20%" (Al Kuwaiti, 2016). The project team needs to identify problems that have the largest impact on the hospital and patients who receive the medication such as those that could harm or cause death to the patient and which are a financial burden to the hospital. In order to ensure that the problem is a high priority, the project team should develop a problem statement, supported by facts and data. The problem statement may include:

- Impact: Does the problem affect patients?
- Severity: How big is the problem from a safety perspective?
- Area: Where does the problem appear? When does the problem appear? How often this problem occurs?

Importantly, the project team should spend enough time to gather sufficient information about the problem. If the project team does not identify the problem carefully, it could lead to the failure of the project (Antony *et al*., 2016). Table 7.2 shows the common tools that can be applied in the define phase.

Table 7.2 Tools used in the define phase

Tools	Description
Voice of the Patient	Voice of the patient is applied to determine what patients need. The project team may conduct focus groups, surveys or interviews with the patients to capture their perceptions.

Process mapping	The project team can use process mapping to understand and identify the current problems in the medication process such as poor flow, rework loops and delays.
Project charter	A project charter is an important tool to help the project team to focus on project goals and clarify the roles and responsibilities of each team member (Bhat *et al*., 2014). It contains the basic details of the project including problem statement, project scope, goal, schedule, etc.

2) Measure Phase

The measure phase aims to collect the data from the current process to measure the baseline performance of the medication process before any improvements. Data collection and analysis is used to ascertain the baseline performance, showing the current state of the problem. Based on the LSS principle, the project team should identify the errors in the process steps and at the end of the medication process. The project team first prepares a data collection plan consisting of types of data to be collected, the person who is responsible for collecting the data, and length of data collection. For example, at an outpatient clinic, pharmacists and nurses are trained to use data collection sheets to record the errors when they find medication errors in a process to collect baseline data regarding medication errors (Chan, 2004). Table 7.3 shows tools and used in the measure phase.

Table 7.3 Tools used in the measure phase

Tools	**Description**
Data collection plan	Data collection plan is developed by the project team to identify the type of data to be collected, how the data are relevant to the problem and (Antony *et al*., 2016) and who is responsible for collecting the data.

Control chart	A control chart is used to understand the stability of the medication process. The project team may use the control chart to draw a conclusion as to whether the medication process is in or out of control. A variety of control charts have been used to display the data: attributes (e.g. p, np, c and u) and variables (e.g. X-R, X-mR) charts (Antony *et al*., 2016). However, P-chart is suitable to show the average proportion of medication errors over time, when the subgroup size is not the same.

3) Analyse Phase

This phase aims to identify the root causes of the problems that contribute to the occurrence of medication errors. Firstly, the project team identifies all the potential causes of the problem through a brainstorming session. All the potential causes are further classified based on different categories: personnel, environment, methods, communication, and presented in a cause and effect diagram. The project team may narrow down the list of potential causes by using a multi-voting tool. Finally, the identified potential causes are further analysed to identify the root causes. Table 7.4 shows tools used in the analyse phase.

Table 7.4 Tools used in the analyse phase

Tools	Description
Cause and effect analysis	Cause and effect analysis is used to identify the potential causes of the identified problems through the brainstorming session with all team members.
Multi-voting	Multi-voting can be used by a project team when the list of potential causes must be narrowed down.
5 Why analysis	5 Why analysis is used to identify the root causes of the problems. It is a potential tool to quickly uncover this aspect.

Value stream mapping	Value stream mapping represents all the important flows of information and materials throughout the complete medication process. It enables the project team to identify of non-valued added activities, bottlenecks and inefficiencies in the process and eliminate them.

4) Improve Phase

The improve phase aims to identify, explore, and implement the solutions. The key output of this phase is the potential solutions that can minimize or eliminate the impact of the selected root causes of the problems. Ideas about the potential solutions can be generated from brainstorming, best practices, published articles or other projects that have encountered similar problems (George *et al*., 2005). Once the solutions are identified, the project team need to check if the potential solutions work effectively to reduce the impact of the problem. After the solutions are identified, the project team may pilot the solution, then implement and observe the results to see if the situation has been improved or not. Table 7.5 summarises the tools that can be used in the improve phase.

Table 7.5 Tools used in the improve phase

Tools	Description
Brainstorming	Brainstorming is a powerful tool to generate ideas from all team members who have experienced and who have been involved in the medication process. Brainstorming can generate effective solutions that can improve the existing medication process.
Process balancing	Process balancing is a useful tool that can be used to reduce the workload of healthcare staff by balancing tasks across process steps and minimizing the number of process steps (George *et al*., 2005).

5) Control Phase

The final phase of DMAIC methodology is to sustain the improvement obtained from the previous phase. The sustainability of the achieved results is challenging and difficult in the healthcare sector. However, the project team can gain the results through three important actions: standardisation; monitoring and training (Antony *et al*., 2016). The procedure of the new methods/process is standardized and placed near to the workstation of the staff (Bhat *et al*., 2016). The staff are trained to follow standard operating procedures so that everyone can perform the same process steps and achieve consistency. The control chart can be used to monitor the number of medication errors over a period of time and to identify when additional process interventions might be required. Table 7.6 summarises the tools that can be used in this phase.

Table 7.6 Tools used in the control phase

Tools	Description
Control chart	In order to control the sustainability of process performance, a control chart is used to sustain the reduction of medication errors over a period of time and to identify when additional analysis might be required (Trakulsunti and Antony, 2018).
Standard Operating Procedures	Standard operational methods provide the details of new methods that can be followed by the staff. It could reduce the medication process variation and ensure consistency.

7.2.4 Phase 3: Sustainability

There is evidence that hospitals have failed to sustain LSS for a long-term (Matteo *et al*., 2011). Most of the previous studies have applied the control phase in the DMAIC methodology to achieve continued improvement; however, this is not possible throughout all organizations (Matteo *et al*., 2011). This phase aims to ensure that the LSS as an initiative of continuous improvement will be sustained and embedded in a hospital's culture for a period of time.

A. Create Lean Six Sigma culture

Creating an LSS culture is an important element to sustaining LSS in the hospitals for a period of time. LSS culture involves encouraging and empowering staff across the hospital and continuously focusing on identifying problems in the medication process and waste, then identifying root causes and developing solutions to minimize them on a continuing basis (Matteo *et al*., 2011). Ensuring staff use LSS methodology every day to solve problems and improve the medication process requires behavioural change, long-term investment, and commitment. To achieve this, staff buy-in is very essential.

The key approaches in getting staff buy-in are: showing and sharing the success stories of LSS throughout the hospital (e.g. reduced medication errors, improved staff morale, and patient safety); using a common language; education and training (Michael, 2002). A reward and recognition system is an important motivating factor to encourage staff to continue implementing LSS in the organizations. Several approaches of reward and recognition can be employed by the organizations such as sharing a financial benefit amongst team members, LSS certification awards, bonuses and promotions (Jeyaraman and Teo, 2010; Antony *et al*., 2018b).

When the staff have 'bought-into' the initiative, they will understand the potential benefits of LSS and how the implementation of LSS can make their life easier, so that they can finally change their working behaviour or the way of working. For example, when staff face problems in the medication process, LSS can be established in the daily routine improvement by asking and answering five questions (see Table 7.7).

Table 7.7 Problem-solving questions

Step	Activity	Ask and Answer
1	Define the issue	What do we need to resolve?
2	Measure what matters	What is the current situation, and the impact on the organization?
3	Analyse the causes	What causes this, and how do we know?
4	Improve the situation	How can it be fixed?
5	Control the future	How do we keep the solution in place?

Source: Geier (2011)

B. Staff knowledge and understanding of LSS methodology

Staff knowledge and understanding of LSS methodology are important factors to drive LSS sustainability. To retain and update staff's LSS knowledge, an LSS refresher workshop is needed periodically. Staff can obtain LSS knowledge via several ways such as in-house training, independent learning, the internet, conferences, and workshops. Moreover, the hospital should continue investment in LSS belts training and certification. The number of LSS experts, particularly Green Belts in the hospital, should be increased in order to enhance the knowledge of LSS across the hospitals (Kowang *et al*., 2016). For example, all middle managers in the hospital should be trained and certified as Green Belt and other staff should be trained for Green Belt to gain promotion (Hoerl, 2001). Harry and Schroeder (2005) also suggested that at least 50 per cent of staff should receive Six Sigma training. The transition of Green Belts or their promotion to be Black Belts, could also increase the number of LSS experts in the hospital.

C. Investor in people (IIP) standard

Leaders are committed towards LSS is a key factor for the sustainability of LSS. The IIP standard can be used to ensure that the leaders are always looking for improvement. The IIP standard is "a UK government-backed scheme aimed at enabling organizations to develop their training and development culture and, thereby, their competitiveness" (Smith *et al*., 2014, p. 266). IIP is a UK-based standard; however, it has been introduced to 66 countries worldwide through Investors in People International (Wilson, 2005; Investors in People, 2020). To become accredited, an organization is assessed against nine indicators that cover three principles: 1) leading; 2) supporting; and 3) improving (Wilson, 2005). Achieving IIP accreditation can improve organizational performance, improve management and enhance quality.

D. Institutionalising Lean Six Sigma

External LSS experts or key members who have experienced with LSS may leave the hospitals to work elsewhere. It is important, therefore, for the hospital to ensure that the benefits from LSS can be sustained in the long term period (Hu *et al*., 2016). Institutionalising LSS is a key factor that can sustain the approach in the organizational culture. It means that the hospital should embed LSS as a part of the hospital. LSS can be institutionalised through the top leader commitment. Leaders play an important role in institutionalising LSS in daily organizational routines. For example, the CEO of the

hospital should ensure that LSS is integrated into exiting strategic plans, operating plans and budgets (Michael, 2002) so that the LSS projects are aligned with the hospital's strategy. Even though consultants and key members leave the organization, the established strategy and principles can still guide its daily operations.

E. Future and trends of LSS

LSS is an ongoing improvement process so that the future and trends of LSS are vital to help healthcare organizations to sustain LSS. Healthcare organizations should continuously adapt to the latest trends of LSS because it is very helpful to generate new ideas to improve the methodology. The LSS emerging trends include: use of robotic process automation (the use of software robots to perform high-volume and repetitive tasks that humans do), using Big Data in decision making in each phase of DMAIC methodology more correctly and quickly, applying Internet of Things (IoT) and integration of LSS into educational systems (Antony *et al*., 2017a; Gupta *et al*., 2019). For example, the use of the radio frequency identification sensor (RFID), an IoT sensor, to identify patients and their corresponding medications in real-time (Paaske *et al*., 2017). Another example is the use of a wearable sensor for Parkinson's disease which improves medication management and patient outcomes (Dimitrov, 2016). However, data security and privacy are the key issues that should be the concern of healthcare organizations. The most widely used technologies to ensure security and privacy are access control, data encryption, monitoring and auditing (Abouelmehdi *et al*., 2018).

F. Succession training

A succession plan is a way of identifying the new leaders which are needed in the future to replace key leaders who depart the organizations. The loss of key leaders who used to support and motive the LSS project team may result in failure in LSS projects or project delay. Ensuring continued leadership buy-in for LSS and long-term leadership commitment is a key factor for sustaining LSS when the leaders who understand about LSS projects have left the hospitals. The hospital should ensure that the people inside or outside the organization who experience and understand LSS are recruited (KPMG international's Healthcare Practice, 2019). Therefore, LSS should include in the criteria for selecting new leaders in a succession plan.

G. Organizational review and strategy review

The LSS project should align with the hospital's strategy in order to sustain LSS across the entire hospital (Cheng, 2013; Goh, 2014; Antony et *al*., 2016). However, when the hospital's strategy is reviewed, the leaders should ensure that the LSS project is incorporated into the organization's strategic imperatives, operating plans, and budgets. To achieve the alignment between LSS project and the hospital's strategy, the following elements should be considered (Pexton, 2020).

- **Staffing**: Have sufficient resources (e.g. time, budget and people) been dedicated?
- **Measurement and accountability:** "Are project supported by the right metrics and aligned with strategic objectives?" (Pexton, 2020, para. 6)
- **Communication:** "Is there a detailed plan in place (who, what, when) to provide clear and consistent communication at all levels of the organization?" (Pexton, 2020, para. 6)

7.3 Chapter summary

This chapter presents the development of the LSS roadmap by explicitly showing a systematic and organized step-by-step methodology. This roadmap can facilitate healthcare practitioners and professionals to apply LSS in a disciplined, organised and systematic way to reduce medication errors. The first phase of the roadmap assesses the cultural readiness to determine whether the organization is ready to employ LSS. The next phase highlights the key factors for preparing the organization to implement LSS such as top management commitment, LSS project selection, team formation and training. The final phases focus on the sustainability of LSS in healthcare organizations. The roadmap can be used as a reference for the implementation of LSS to reduce medication errors.

CHAPTER 8 – DISCUSSION OF KEY FINDINGS

8.1 Introduction

Chapters 5 and 6 presented the key findings from the action research which was undertaken in Hospital A and Hospital B. Chapter 7 proposed a roadmap for LSS implementation and sustainability to guide healthcare practitioners in the reduction medication errors. The aim of this chapter is to discuss the key findings with respect to the following research questions.

Research Question 1: What is the current status (benefits, challenges, success factors) in the use of Lean Six Sigma to reduce medication errors in a global context?

Research Question 2: What are the benefits, challenges and success factors in the use of LSS to reduce medication errors in Thai Hospitals?

Research Question 3: What tools and techniques of Lean and Six Sigma can be utilized to reduce medication errors?

Research Question 4: How can an LSS implementation and sustainability roadmap be developed to guide healthcare practitioners in the reduction of medication errors?

8.2 The current status of Lean Six Sigma to reduce medication errors globally (Research Question 1)

The review of the literature reveals that a key benefit of LSS is the reduction of errors in the medication process. This finding is in line with the previous review of LSS in healthcare conducted by Ahmed *et al.* (2013), indicating that medication error reduction was one of the key benefits of LSS application in the healthcare sector. The results clearly show that LSS provides potential benefits for hospital management and providers. However, there are remaining challenges when there is a lack of top management support and regarding the availability of data. This finding is similar to that of Albiliwi *et al.* (2014). These authors identified the lack of top management commitment as the most important factor leading to failure in implementing LSS in different sectors such as manufacturing, services, higher education, and healthcare.

The current study found that the critical success factors of LSS when implemented to reduce medication errors are very similar to the critical success factors in healthcare

sectors in several aspects. These include the appropriate training and education, staff commitment to process improvement, and understanding of LSS methodology and its associated tools and techniques. In healthcare, many researchers have mentioned that project selection and prioritization is critical to the success of the project (Antony *et al*., 2007; Desai *et al*., 2012; Bhat *et al*., 2016). However, this factor has not been mentioned in the context of medication errors. A possible explanation for this may be that most of the studies are case studies which aim to apply LSS in a particular organization, so the authors have already selected the project without an explanation as to how it was prioritized and selected. However, when the maturity of LSS implementation in the hospitals increases, the project prioritization and selection should be considered by the hospitals. As the hospitals deal with different types of project from various departments, the project can be selected by considering the impact (e.g. save patients live, reduce hospital costs) against the hospital effort (e.g. resources).

8.3 The benefits, challenges and success factors when using Lean Six Sigma to reduce medication errors in Thai Hospitals (Research Question 2)

The second question (see section 8.1 above) sought to identify the benefits, challenges and success factors in the use of LSS to reduce dispensing errors in the inpatient pharmacy in the context of Thai hospitals.

8.3.1 Benefits of LSS

The findings of this study show that the use of LSS methodology in two hospitals contributed to considerable benefits. These benefits included: 1) reduced dispensing errors; 2) improved process flow; 3) improved staff morale; 4) improved communication channels between pharmacists and pharmacy technicians; 5) increased patient satisfaction; and 6) improved patient safety. Such benefits can be classified into three types: operation excellence, staff focus, and patient focus, as summarised in Table 8.1.

Table 8.1 The benefits of LSS implementation from Hospital A and Hospital B

Classification	Outcome category
Operational excellence	Reduced dispensing errors (both detected and undetected by the pharmacists)
	Improved process flow

Staff focus	Improved staff morale Improved communication channels between pharmacists and pharmacy technicians
Patient focus	Improved patient satisfaction Improved patient safety

Source: adapted from Antony *et al.*(2018b)

The findings from both hospitals show that the successful LSS implementation can reduce process variation. SD variation reduced from 0.0083 to 0.0074 in Hospital A and 0.0033 to 0.0028 in Hospital B; as a result, the average proportion of undetected dispensing errors was reduced by 65% in hospital A, and 33% in hospital B. This finding was also reported by Chan (2004), who applied Six Sigma in the outpatient department and reduced dispensing errors by 30%. However, Chan's study did not include the benefit of process flows.

Moreover, this finding is also consistent with those of Ching *et al.* (2013) and Chiarini (2012) whose implementation of the DMAIC methodology resulted in the reduction of errors relating to administered medication doses and parenteral medication administration. This finding supports Trakulsunti and Antony's (2018) study which identified that the key benefit of LSS methodology is the reduction of errors in the medication process, particularly in the dispensing and administration phases.

Furthermore, the findings show that the implementation of LSS not only reduces the number of undetected dispensing errors, but also the errors detected by pharmacists including incorrect selection of medications and incorrect entry of medication order. In contrast, the previous studies that implemented LSS to reduce dispensing errors did not distinguish between the errors detected within or outside the pharmacy department (Chan, 2004; Al kuwaita, 2016).

The current study found that the dispensing process flow was improved due to the elimination of non-value added activities during medication preparation, and this was another key benefit reported by Hospital A. This finding is in accord with Hintzen *et al.* (2009) who applied Lean tools in an inpatient pharmacy and identified that improvement in workflow was one of the key benefits. However, improvement in the dispensing process flow has not been reported by Hospital B because the hospital had, since 2008, already implemented Lean tools such as spaghetti diagram to improve the dispensing process flow.

In addition, the results from this study indicated that the top three causes of incorrect medication selection were: non-compliance with the medication selection standard procedure, technicians reporting that they were too rushed, and the workload was imbalanced. These findings are in line with those from Kaosayapandhu (2013), Aldhwaihi *et al.* (2016) and Rajah *et al.* (2018). In a study of dispensing errors in an outpatient pharmacy in six Malaysian hospitals, distractions and an interrupted work environment were cited as the leading cause of dispensing error (Rajah *et al*., 2018).

Improved staff morale was another key benefit emerging from both hospitals. The staff involved in both hospitals were very satisfied with their new routine and their quality of life. Quotes by participants identified that *'We were very satisfied with the new distribution of our routine jobs. It decreased a lot of tasks that I needed to do daily'* and *'I was very happy when I worked, and I felt that my life was better than before'.* Similarly, Esimai (2005) implemented LSS in a hospital to reduce the incorrect entry of medication orders and concluded that improved staff morale was one of the key LSS implementation benefits. However, Esimai's study lacked clarification of the details of how LSS can improve staff morale and did not mention how to identify it. In this current study, an interview was conducted with participants to capture their views after the implementation of LSS through the action research methodology.

Another benefit found with both hospitals was that LSS improved the communication channels between the pharmacy and pharmacy technicians. The action research project provided them an opportunity to work together and solve the problems in the dispensing process. However, this finding has not been described previously. This might be because the previous studies did not undertake interviews with participants to understand the team members' perspectives after the LSS project. Previous published studies have focused on reducing errors, but they did not ascertain the views of participants (Esimai, 2005; Benitez *et al*., 2007; Al Kuwaiti, 2016).

Another important benefit of LSS reported by both hospitals was the improvement in patient satisfaction. This finding is consistent with that of Esimai (2005) and Benitez *et al.* (2007) who identified that improved patient satisfaction was one of the benefits of LSS application in the mid-sized US hospitals. However, Esimai's and Benitez *et al's* (2007) study did not mention how they measured patient satisfaction. On the other hand, the current study used questionnaires to evaluate patient satisfaction with the quality of pharmacy services before and after the implementation of LSS.

Overall inpatient satisfaction in both hospitals increased after the LSS implementation: Hospital A; pre (mean=4.00, SD=0.56) post (mean=4.38, SD=0.45) and Hospital B; pre (mean=4.28, SD=0.46) post (mean=4.98, SD=0.43). It can be considered that previous studies lacked rigorous measurement of patient satisfaction, even though they identified it as an important benefit of LSS application.

Antony *et al.* (2007) stated that it is difficult to measure patient satisfaction in a hospital environment owing to human behaviour (e.g. honesty and friendliness) associated with the delivery of healthcare service. It is certainly the case that it is difficult to evaluate patient satisfaction when they are in hospital. For example, patients usually do not know the medication that nurses administer to them and, therefore, they are unable to judge the medications that they receive. Moreover, it is only possible to evaluate satisfaction with those patients who are well enough to answer questions. The use of VOC varies according to the cultural difference across countries. In Thailand, the VOC is poorly executed to understand the needs of patient. Moreover, it is also difficult for healthcare practitioners to measure patient satisfaction as they are too busy. Nevertheless, it can be argued that it is still important to attempt to measure patient satisfaction before and after LSS implementation as the LSS principle focuses on patient needs.

Another important finding was that prevention of dispensing errors before they reach patients leads to improved patient safety as dispensing errors can lead to patient harm, death or even disability. Similarly, Critchley (2015) and Hussain *et al's.* (2015) study identified that the employment of Lean can improve patient safety by reducing the rate of serious harmful events in the hospital

8.3.2 Challenge of LSS

Table 8.2 presents the main challenges of LSS implementation that emerged from Hospitals A and B, and the researcher's reflection. These challenges included: resistance to change, lack of effective communication, insufficient resources and inadequate knowledge of LSS.

Table 8.2 Challenge classification from LSS implementation to reduce medication errors

Classification	Challenge
Six Sigma related challenge	Inadequate knowledge of Lean Six Sigma (the researcher's own reflection)

During implementation	Resistance to change (Hospital A and Hospital B) Insufficient resources (the researcher's own reflection)
Staff related challenge	Lack of effective communication (Hospital A)

Source: adapted from Antony *et al.* (2018b)

The findings of this study show that resistance to change was a major challenge encountered by the project team in both hospitals. It is indeed one of the major challenges faced by healthcare organizations globally (Albiliwi *et al*., 2014). This finding is consistent with that of Castle *et al.* (2005) who reported that it was difficult to convince healthcare staff with regard to making changes in routine tasks. Resistance to change is a common response when people are expected to differ from their normal routine (Jadhav *et al*., 2014), hence it is critical to clarify the need for change and benefits accruing to all staff involved in the LSS project. However, the main challenge in the use of LSS in healthcare and in the reduction of medication errors is the difficulty in obtaining baseline data on process performance (Sehwail and DeYong, 2003; Castle *et al.* 2005; Taner *et al.* 2007; Antony *et al.* 2007). A recent systematic review by Antony *et al.* (2018b) also identified that one of the most challenging issues in the use of Six Sigma in healthcare is the availability of data. However, it can be argued that the hospitals have substantial data available, but this has often not been analysed or used this data in problem-solving.

Another challenge found with Hospital A was the lack of effective communication between the project team and other staff in the inpatient pharmacy or between departments (e.g. the inpatient pharmacy and wards). A possible explanation for this might be that there is a Thai communication style which is indirect and sensitive to hierarchy. This finding is consistent with that of Antony *et al.* (2012) who indicated that lack of communication was among major problems and challenges encountered in implementing healthcare industry continuous improvement initiatives. However, ineffective communication has not previously been mentioned in the literature as a challenge of LSS implementation in reducing medication errors. This study suggests the importance of accurate communication about LSS to all healthcare staff involved in the medication process and between departments.

One interesting finding was that insufficient resources and inadequate knowledge of LSS were major barriers of LSS deployment that had not emerged from the interviews with participants from both hospitals. These challenges were identified from the researcher's

own reflections (in section 5.5 and 6.5). Insufficient resources (e.g. time and budget) and knowledge of LSS were major challenges when applying LSS in healthcare as reported by several authors such as Taner *et al.* (2007) and Antony *et al.* (2018b). In this study, participants' time commitment was an immense problem even though the project timeline had been made available to participants at the beginning of the project. All participants from both hospitals were working full-time in the inpatient pharmacy and, therefore meetings, focus groups and interviews were conducted mostly at lunchtime. The present study raises the fact that providing sufficient and appropriate allocated time, budget or other resources are all important for effective and timely project completion.

Insufficient knowledge of LSS was a challenge that had been identified prior to the project. Some of the participants from both hospitals had a little knowledge of Lean, but none of the participants had any knowledge of Six Sigma. This challenge is consistent with the findings of Aboelmaged (2011) who conducted a survey on the barriers of Six Sigma deployment in developing countries. The results showed that a lack of knowledge about Six Sigma was one of the challenges in implementing Six Sigma in such countries.

This was similar to a case study carried out in Thailand by Nonthaleerak and Hendry (2007). These authors identified that a lack of knowledge of tools was one of the causes of Six Sigma failure. It can be suggested, therefore, that there is a lack of awareness of the benefits of LSS in Thai Hospitals as well as knowledge of the relevant tools. However, in the current study, the researcher has trained the participants to understand the LSS principles and tools and techniques to be used in each phase of DMAIC methodology.

8.3.3 Critical success factors of LSS to reduce medication errors

Table 8.3 identifies factors deemed critical to LSS implementation success with respect to medication error reduction in Hospitals A and B. The findings of the critical success factors of LSS are slightly different between these two hospitals. The underlying cause that led to the difference of critical success factors between Hospitals A and B is the implementation of computerised physician order entry (CPOE) and quality improvement awareness. As hospital B had already implemented CPOE and Lean tools, the dispensing process in Hospital B was less complex than Hospital A, and the problems identified from dispensing process were different. Another cause would be the diversity of the team members because most of the participants from Hospital B were middle managers in the pharmacy department.

Table 8.3 Critical success factors of LSS emerged from Hospital A and Hospital B

Hospital A	Hospital B
Understanding of LSS methodology and its tools and techniques	Understanding of LSS methodology and its tools and techniques
Middle management support and involvement	Top management support
Creativity and problem-solving skills	
Leadership	

These factors were also reported as critical success factors of LSS employment in the literature (Hintzen *et al*., 2009; Snee, 2010; Ching *et al*., 2013; Tsironis and Psychogios, 2016; Alhuraish *et al*., 2017). Understanding LSS methodology, tools and techniques were also cited as critical success factors for the implementation of LSS in healthcare (Taner *et al*., 2007; Alhuraish *et al*., 2017). However, the finding from Hospital B revealed that not only the participants should understand LSS, but also all staff in the inpatient pharmacy. This finding from Hospital B is contrary to previous studies which have not mentioned that all staff in the inpatient service should understand and/or receive LSS training. It suggests that an understanding of LSS tools and techniques and its philosophy by staff at all levels in the hospitals, particularly those involved in the medication process, is important to the success of the LSS project. However, the considerable investment in both time and cost of this should not be ignored.

Management support was another key factor that ensured the LSS project's success in both hospitals. This finding is consistent with other research which has found that top management commitment and involvement is a critical factor for successful LSS deployment in healthcare (Alhuraish *et al*., 2017; Tsironis and Psychogios, 2016). However, the level of management that facilitated the LSS project in the two hospitals was different. As most of the participants in Hospital B were middle managers, they required support from top management to facilitate the implementation of LSS. Nevertheless, in Hospital A, there were several changes that occurred in the medication process which were promoted by the head of inpatient pharmacy and, therefore participants perceived that the support from the middle manager was a key success factor.

Creativity and problem-solving skills and leadership were success factors that emerged from Hospital A. Although rarely cited in the literature, team members' creativity and problem-solving ability can generate potential solutions and contribute to effective LSS

use and implementation. Previous studies have mentioned that identifying appropriate team members (Castel *et al*., 2005) and selecting the right people (Antony *et al*., 2007) are key enablers of successful LSS projects. As such, the selection of appropriately skilled team members to execute LSS projects, including when addressing the challenges of the medication process are endorsed. Essential skills required for team members are creativity and problem solving, integrity and technical expertise (understanding data and analysis) (Antony, 2014). Interestingly, this finding has not emerged from Hospital B. This might be due to the fact that the nature of the problems of these hospitals was different. Hospital A had encountered two main problems and required multiple brainstorming sessions to generate potential solutions from team members.

Leadership was a critical success factor leading to the success of the LSS project in Hospital A. This finding have also been reported by Pamfile *et al.* (2012) who indicated that leadership is necessary to motivate and encourage staff in healthcare organizations through involvement in LSS projects. However, leadership has not been mentioned by participants from Hospital B as a key success factor. It can, therefore, be assumed that half of the participants were middle managers in the pharmacy department.

Other critical success factors such as project selection and prioritization and specifying LSS infrastructure did not emerge from either hospital. At the beginning of the project, both hospitals were willing to make changes in the dispensing process to reduce medication errors. The LSS project to reduce medication errors became the most important project for both hospitals. In addition, specifying LSS infrastructure was not mentioned as a success factor for either hospital. This might be due to the lack of LSS awareness so that none of the participants had received LSS training from an external expert.

8.4 Tools and techniques of Lean and Six Sigma used to reduce medication errors (Research Question 3)

The current literature highlighted that very few studies have used pure Lean, Six Sigma and LSS to reduce medication errors. Moreover, previous studies have shown a lack of understanding as to how to use LSS tools and techniques. In this study, the appropriate Lean and Six Sigma tools and techniques were implemented across the DMAIC methodology for reducing medication errors.

8.4.1 Lean tools

The results from both hospitals show that Lean tools selected for application in this study included process mapping, spaghetti diagram, value stream mapping, visual process control, and standard operating procedure. A similar finding was reported by Trakulsunti *et al.* (2018), who identified the five leading Lean tools widely used to reduce medication errors as process mapping, spaghetti diagram, visual process control, standard operating procedure, and Poka-yoke. However, Poka-yoke was deemed inappropriate for use in this study. As mentioned in the literature, some examples of mistake-proofing devices which have been used to avoid medication errors include using an automatic dispensing machine (Chan, 2004), barcoding (Chiarini, 2012) and an online medication ordering system (Kumar and Steinebach, 2008). This study could not implement these devices due to financial and time constraints. Spaghetti diagram was used to visually present the unnecessary movement of the pharmacy technicians in the inpatient pharmacy in Hospital A, which contrasted with other studies, possibly because the layout of previous studies were not complicated.

While process balancing was used in this study, it had not been applied in previous studies. The findings from the application of process balancing in Hospital B show that the unbalanced workload between each position when pharmacy technicians collected medications was the root cause of the incorrect selection of medications. Therefore, evenly distributing the workload between the workstations was required in this study. As mentioned in the literature, the workload is the primary cause of the occurrence of errors in the medication use process. However, previous published studies have been limited in their use of process balancing to balance tasks across all process steps.

In summary, the key benefits of Lean tools are easy to apply and use by healthcare staff and the application of Lean tools does not require highly skilled staff (Hu *et al*., 2016).

8.4.2 Lean and Six Sigma tools used in various phases of DMAIC methodology

Table 8.4 shows Lean and Six Sigma tools and techniques that were implemented across the DMAIC methodology in Hospitals A and B.

Table 8.4 Lean and Six Sigma tools used in various phases of DMAIC methodology

Six Sigma Methodology	Hospital A	Hospital B
Define	Project charter In frame/out of frame Process mapping Spaghetti diagram	Project charter In frame/out of frame Process mapping
Measure	Data collection planning Critical-to-quality (CTQ) Pareto charts P-control chart	Data collection planning Critical-to-quality (CTQ) Pareto charts P-control chart
Analyse	Cause and effect analysis Multi – voting 5 Why analysis	Cause and effect analysis Multi – voting 5 Why analysis
Improve	Brainstorming Visual process control	Brainstorming Process balancing
Control	P-control chart Standard operating procedures Hypothesis testing	P-control chart Standard operating procedures Hypothesis testing

In the define phase, the findings from both hospitals showed that process mapping was used to identify problems leading to dispensing errors. Castle *et al.* (2005) applied process mapping to a home-delivery pharmacy service in the define phase, to understand the process flow and identify process steps to be improved. It can be observed that spaghetti diagram was not used in Hospital B in this phase because it had been implemented to improve the dispensing process flow since 2008. The dispensing process flow in Hospital A is more complex than Hospital B due to the use of different medication distribution systems. Hospital A performs many process steps to deliver medications to patients. Furthermore, Hospital A has never implemented Lean tools to improve the dispensing process.

A Project charter was also employed in the define phase to identify the project's scope and goal. While project charters are commonly used in healthcare, no existing literature was found to indicate the use of a project charter in the define phase in the context of medication errors (Trakulsunti *et al*., 2018). As mentioned by Trakulsunti and Antony (2018), there is still a lack of use of common tools such as a project charter in the define phase; therefore, this study was able to fill this gap.

Data collection planning, CTQ characteristics, control charts and Pareto charts were used in the measure phase. This mirrors the findings of Antony *et al.* (2018b) in a systematic review of Six Sigma application in healthcare and identified these to be among the five

leading measure phase tools. In this study, a P-control chart was used to assess baseline dispensing process performance in both hospitals. However, literature indicates that control charts have not previously been used to establish current process performance in the context of medication dispensing errors in the measure phase.

The result shows that a P-chart was used to estimate the average proportion of dispensing errors and to monitor the dispensing process was in statistical control. For example, Chan's (2004) study used historical data as a baseline performance. The weakness of Chan's (2004) study, however, was a lack of providing information about dispensing errors that occurred each month. This study would be more useful if the author had employed a control chart to show the percentage of dispensing errors on a monthly basis. Additionally, a Pareto chart was also used in the current study to pinpoint the rate of occurrences and type of incorrect medication errors in both hospitals, and incorrect entry of medication orders in Hospital A. This finding was also reported by Esimai (2005) who used the Pareto chart to prioritize the frequency of the occurrence of errors made by the pharmacists.

In the analyse phase, the findings from both hospitals revealed that cause and effect analysis, multi-voting, and 5 Why analysis were used to identify dispensing process problems root causes. Existing literature has identified brainstorming as most commonly used tool to identify the cause of the errors in the medication process (Castle *et al*., 2005; Esimai, 2005; Benitez *et al.*, 2007; Nayar *et al.*, 2016). The current study used 5 Why analysis to uncover root causes of the problems that contributed to the occurrence of dispensing errors. However, no previous studies have applied any tools or techniques to identify the root causes of dispensing errors. As mentioned in the literature, the common tools used to identify the root causes in the healthcare sector are Gemba and hypothesis testing (Gijo *et al.*, 2013; Bhat *et al*., 2016). However, due to the different potential root causes, the current study could not use hypothesis testing. It can be argued nevertheless that 5 Why analysis is useful in healthcare contexts, because of its ease of application.

In the improve phase, the findings from both hospitals showed that there was a slight difference between the tools used in this phase because the nature of the problems and their root causes were different in each hospital. The findings from both hospitals showed that brainstorming was used by both hospitals. It is a commonly used improve phase tool (Chan, 2004; Castle *et al.*, 2005; Esimai, 2005; Al Kuwaiti, 2016) because it generates potential solutions from process experts and practitioners.

However, for the improve phase, several studies have implemented various aspects of information technology such as a barcode system, an automatic dispensing machine, and an automated pharmacy carousel system to reduce pharmacy medication errors (Halkin *et al.*, 2001; Poon *et al.*, 2006; Oswald and Caldwell, 2007). Implementation of these requires large capital investments and maintenance; therefore, not all of the hospitals can implement such technologies. For example, Chaiyakunapruk *et al.* (2016) noted that general Thai hospital pharmacy practice had not reached its best standard of practice due to limited financial support and lack of up-to-date technology. In addition, one of the potential solutions was the re-design the process of daily dose medication preparation in Hospital A. This solution is in line with prior findings that redesigning pharmacy work processes can reduce workloads and improve work environments that contribute to dispensing errors (Sanguansak *et al.*, 2012).

Finally, the control chart and standard operating procedure were used in the control phase to sustain the results over a period of time. This finding was similar to that of Chan (2004), Castle *et al.* (2005) and Benitez *et al.* (2007), whereby a control chart was implemented in the final phase. However, few studies have graphically presented the control chart. Furthermore, a hypothesis test was used to compare the proportion of dispensing errors before and after LSS implementation. However, in contrast to the previous studies, hypothesis tests were also applied during the analyse phase to validate possible root causes identified by cause and effect diagrams (Gijo *et al.*, 2013; Bhat *et al.*, 2014). Additionally, no prior studies use hypothesis testing to compare the process pre and post the improvement. This finding suggests that hypothesis tests should be included in the control phase to test the proportions of errors before and after the improvement.

It can thus be suggested that in service organizations, particularly in hospitals, the problems could be tackled by using the simple tools of LSS toolboxes. The hospitals were not previously using these tools because of the staff lack of knowledge and there was no data-driven culture within both hospitals (Antony *et al*., 2017b). Similarly, Lifvergren *et al.* (2010) confirmed that the use of advanced statistical tools in every phase of DMAIC is not required to achieve successful results. In contrast, Bhat *et al.* (2014) suggested that statistical and advanced statistical tools are of value in service sectors if the team members receive an LSS Belt training programme so that they can understand and use them properly. In this study, however, the researcher was the only team member to have undertaken Green Belt training and the others were not familiar with the application of advanced statistical tools.

8.5 LSS roadmap to reduce medication errors (Research Question 4)

In this study, the LSS implementation and sustainability roadmap was developed to reduce medication errors because the existing literature does not provide an LSS roadmap to guide healthcare practitioners in reducing medication errors. This roadmap was developed based on the work pursued by other research scholars including Kumar *et al.* (2011), Al-Balushi *et al.* (2014), Antony *et al.* (2016), Timans *et al.* (2016), and Alnajem *et al.* (2019) and the execution of the action research. In contrast to the previous studies, most of LSS frameworks/roadmaps proposed for healthcare sectors have been developed from the existing literature rather than through an empirical study. Most of the proposed frameworks in healthcare organizations have used DMAIC methodology as an LSS framework (Yeh *et al*., 2011; Chenge and Chang, 2012; Furterer, 2014; Honda *et al*., 2018; Al-Qatawneh *et al*., 2019).

The LSS roadmap developed in this study is different to previous studies in several respects. First, it focuses on how to implement LSS successfully by considering the readiness factors and the application of LSS methodology along with its tools and techniques. Second, it concentrated on how to sustain the LSS in healthcare organizations for a period of time. Lastly, it was validated by LSS experts and a healthcare practitioner. In this study, the decision point and timeframe have been added into the roadmap to ensure that the healthcare organizations involved in the project can successfully implement LSS to reduce medication errors.

8.6 Use of DMAIC methodology to reduce medication errors

The current study found that the DMAIC methodology can be applied to the inpatient pharmacy in order to reduce dispensing errors. This is in line with key findings from Al Kuwaiti (2016) where DMAIC was applied in an outpatient pharmacy of a Saudi Arabian hospital. The results of that study showed a marked reduction in medication errors. Meanwhile, Castle *et al.* (2005) demonstrated that the implementation of the DMAIC methodology led to a reduction in the dispensing rate and number of several types of medication. This finding is consistent with that of Chan (2004) who implemented DMAIC methodology to reduce dispensing errors in a pharmacy department. However, in the analyse phase, Chan's study did not incorporate Lean or Six Sigma tools to identify the root causes of the problems. This finding has important implications for using the correct tool at the relevant phase of DMAIC methodology.

Moreover, in the current study, the findings from both hospitals indicated that the application of DMAIC methodology facilitated the participants to understand where the problems lay in the dispensing process. The study found that the five steps of DMAIC were easy to follow and were understood by participants. This finding is in accord with Snee (2010) and Antony *et al.* (2016) indicating that DMAIC methodology is easy to follow to determine the root causes of problems within processes (Antony *et al*., 2016; Snee, 2010). When the dispensing errors had occurred, the pharmacists generally conducted a brainstorming session to identify the causes of the problems, and then generated the solutions. The root causes of the problems remained in the dispensing process because top management did not provide resources for training staff about quality improvement. It can thus be suggested that the success of DMAIC methodology relies on the sequential steps of the methodology.

8.7 Value stream mapping to reduce patients' relatives waiting time

The result shows that VSM can be used to reduce patients' relatives waiting time to receive medication. VSM has been applied as one of the Lean tools by several studies to reduce patient waiting in an outpatient department (Gijo and Antony, 2014), a pathology department (Gijo *et al*., 2013), and a radiology department (Camgoz-akdag *et al*., 2017). However, a search of the literature reveals that there is limited published research using VSM to reduce waiting time in the pharmacy service. Previous studies within pharmacy department have implemented various techniques and technological interventions to reduce patient waiting time such as automated queuing technology, system modelling and simulation and automated pharmacy systems (Alam *et al*., 2018). As mentioned in the literature and above, the implementation of technology requires a large investment for installation and maintenance. It can be argued that VSM is a valuable tool that can be used at a starting point to understand how the medication process is currently performed. VSM visually presents the flow of material, information and people so that it can identify wastes, duplicate process steps and problems.

8.8 Chapter summary

This chapter discussed the key findings from the action research within both hospitals in relation to the existing research literature. Unexpected findings were also explored. The present findings are significant regarding at least three major aspects: 1) LSS methodology assists hospitals to reduce medication errors and improves patient safety; 2) Selection of the right LSS tools and technique is a major component in the successful

implementation of LSS, and 3) healthcare practitioners can follow an LSS implementation and sustainability roadmap to reduce medication errors. The next and final chapter of this thesis summarises the main research findings and identifies the practical contributions of this research.

CHAPTER 9 – CONCLUSIONS, CONTRIBUTION TO RESEARCH AND SUGGESTIONS FOR FUTURE RESEARCH

9.1 Introduction

This chapter presents how the aim of the research has been achieved. The first section highlights the key findings in relation to the research questions identified in Chapter 1. The next section explains the practical contribution of the research, followed by the limitations of the research. Then, suggestions for future directions arising out of the research are described. The final section presents the researcher's reflection throughout the research process, showing experiences and knowledge gained from conducting the research.

9.2 Critical reflection on the research aim

The aim of the research was to develop an LSS implementation and sustainability roadmap to be followed by healthcare practitioners to reduce medication errors. The previous studies do not provide an LSS roadmap for healthcare practitioners to follow in order to successfully implement LSS to reduce medication errors and sustain LSS in their organizations. Most of the existing frameworks have used DMAIC methodology as the LSS framework (Yeh *et al*., 2011; Cheng and Chang, 2012; Furtherer, 2014 and there is no framework/roadmap identified in the current literature which focuses on how to sustain LSS across the healthcare organization. This study proposes an LSS roadmap for reducing medication errors and embedding LSS across the organization. This roadmap can facilitate healthcare practitioners to apply LSS in a disciplined, organised and systematic way to reduce medication errors.

9.3 Critical reflection on the research questions

To achieve this aim, four research questions were explored, and the findings and their discussion were presented in previous chapters. The following sections consider how the research question were answered.

Research Question 1: What is the current status (benefits, challenges and success factors) in the use of Lean Six Sigma to reduce medication errors in a global context?

The systematic literature review revealed that there has been a noticeable increase in the interest for Lean, Six Sigma and LSS application to reduce medication errors, especially in the developed countries (Trakulsunti *et al*., 2018). However, Lean Six Sigma application in developing countries such as Thailand is at an early stage. The review identified that Lean and Six Sigma methodologies, including their tools and techniques, benefits, challenges and success factors of application in the context of medication errors, had not been reported before. The results of the current research showed that strong leadership and awareness of Lean and Six Sigma effectiveness at the top management level in the hospital is critical to improving outcomes, with the lack of senior management buy-in as a leading factor in the lack of improvement.

This finding suggests that healthcare practitioners should consider the challenges of LSS such as lack of top management support and availability of data before embarking on an LSS project. Project team members should understand the purpose of the Lean and Six Sigma philosophy and its tools and techniques as well as undergoing training. However, training alone cannot guarantee the successful completion of projects. Effective coaching and mentoring by LSS project champions and the right choice of projects are also imperative.

Research Question 2: What are the benefits, challenges and success factors in the use of Lean Six Sigma to reduce medication errors in Thai Hospitals?

The present study appears to be the first study that has focused on a continuous improvement methodology to improve the dispensing process in the inpatient pharmacy in public hospitals. This study clearly indicates that the implementation of LSS and its associated tools and techniques can reduce medication errors and improve the quality of care. A key finding emerging from this study was resistance to change as the main challenge encountered by the project team. However, the study highlights that an understanding of LSS methodology and management support were key success factors in overcoming these challenges.

The findings from this study make several contributions to the current literature. First, the employment of LSS through collaboration between an outside researcher and healthcare practitioners can create change in the dispensing process, and improve staff communication as well as the quality of care. Second, the proper implementation of LSS can increase staff morale and patient satisfaction (based on the interviews with participants and survey with inpatients as identified in Chapters 5 and 6). Third, it enables

all the staff who are involved in the medication process to have a fundamental knowledge of LSS and its tools and techniques. With the dual aims of process improvement and improving the bottom line, LSS appears to be the best choice for hospitals to achieve process improvement and cost savings. Similar projects in hospital setting elsewhere would have the potential to reduce errors in every phase of the medication use process, from prescribing, transcribing, and dispensing to the administration of the medication.

Research Question 3: What tools and techniques of Lean and Six Sigma can be utilized to reduce medication errors?

This study has been one of the first attempts to use appropriate tools and techniques of Lean and Sigma in the right phase of DMAIC methodology. In the define phase process mapping and spaghetti diagram were used to identify problems leading to errors in the dispensing process. Project charter was used in this phase to help the project team focus on the same goal. In Frame/Out of Frame tool was also used to ensure that the project team members had a clear understanding of project scope. Next, in the measure phase, CTQ was used to translate voice of the patient into the measurement form. Data collection plan, Pareto chart, and control chart were used to ascertain the baseline performance of the dispensing process, showing the current state of the problem. Cause and effect analysis, multi – voting and 5 Why analysis were used to identify the cause and root causes of the problems in the analyse phase.

The next phase was the improve phase, whereby the tools used in this phase were brainstorming, and visual process control. Finally, in order to control the sustainability of process performance, control charts and standard operating procedures were used to sustain the reduction of medication errors over a period of time. The most obvious finding to emerge from this study is that most of the tools used in various phases of DMAIC methodology to reduce medication errors were non-statistical tools. Advanced statistical tools such as design of experiments (DOE) and regression analysis in manufacturing may not be necessary to apply in healthcare sectors. Moreover, the findings in this study provide a new understanding of the application of Lean and Six Sigma tools to mitigate the number of medication errors and improve patient safety.

Research Question 4: How can an LSS implementation and sustainability roadmap be developed to guide healthcare practitioners in the reduction of medication errors?

There is limited research which provides a Lean, Six Sigma or LSS roadmap for healthcare practitioners to follow for reducing medication errors in their hospitals. An LSS implementation and sustainability roadmap has been developed for healthcare practitioners to guide them in the implementation and deployment of LSS along with its tools and techniques. This roadmap was developed based on the existing frameworks for LSS implementation and the execution of the action research. The roadmap for LSS in reducing medication errors includes three phases. The first phase of the roadmap assesses the cultural readiness to determine whether the organization is ready to employ LSS. The next phase highlights the key factors for preparing the organization to implement LSS such as top management commitment, LSS project selection, team formation, and training. The final phases focus on the sustainability of LSS in healthcare organizations. The study has shown that the LSS roadmap could facilitate and guide healthcare practitioners in the successful implementation of LSS to improve the medication process and to sustain LSS in their hospitals. However, in order to ensure that the hospital is ready to implement LSS, it is important to assess the readiness factors to determine whether the organization is ready to employ LSS.

9.3 Research contribution

9.4.1 Practical contribution

The key findings from the systematic review can be used as a guideline for healthcare practitioners and professionals before the implementation of an LSS project to reduce medication errors by considering their benefits, challenges and success factors (Trakulsunti and Antony, 2018). This study would be of interest to hospitals, with the dual aims of improving patient safety and enhancing quality of care. This study is valuable for healthcare sectors seeking to reduce errors in the medication process or other processes that need to improve. Also, this study is appropriate for hospital managers looking for changes in pharmacy services or other departments.

This study provides a greater awareness for senior managers and medical directors in hospitals about the role of LSS and its associated tools and techniques in tackling medication errors. Moreover, it provides a clear understanding of the current status of LSS implementation in the reduction of medication errors. The different tools and techniques of Lean and Six Sigma used across the DMAIC methodology can be followed by healthcare practitioners in tackling medication errors. Most of the tools and techniques used to reduce medication errors were non-statistical so that they are easy to apply by

healthcare practitioners. Moreover, the study has illustrated that problems could be solved through a simple solution without major investment. This could motivate hospital managers or hospital directors regarding the implementation of LSS to reduce medication errors in their hospitals.

The study has suggested that it is vital to select appropriately skilled team member to execute an LSS project and address medication process problems. Essential skills required for the project team members are problem-solving, integrity and technical expertise (understanding data and analysis) (Antony, 2014). Moreover, it is important for the project team to select the most appropriate LSS tools in addressing the medication process improvement. The success of an LSS project is also dependent upon the allocation of sufficient time from team members.

Hospitals can improve the medication process by following the LSS implementation and sustainability roadmap, which can be used as a guideline for healthcare practitioners to reduce medication errors. The roadmap is explained step by step and is easy to follow by healthcare practitioners, and it enables the healthcare practitioners or hospital managers to understand how to initiate, implement and sustain LSS in their organizations. This roadmap could facilitate healthcare practitioners to apply LSS in a more disciplined, organised and systematic way.

9.5 Limitations of the research

The limitations of this study have been identified as follows.

- In chapter 2, the search strategy was limited to English-language studies and did not include unpublished abstracts from conference proceedings or non-indexed journals (Hesselink *et al*., 2012). The review may have been influenced by publication bias, in which unpublished studies on this subject may have inconclusive results (Hesselink *et al*., 2012; Balaid *et al.*, 2016).
- The scope of this study was limited in terms of it being context-specific. The study was undertaken in the inpatient pharmacy in two public hospitals in Thailand. The findings from the action research methodology cannot be generalized beyond the specific setting (Montgomery *et al*., 2015). However, the dissemination of findings could be applicable or inform similar contexts or situations that share the same features.

- Another potential limitation of the study is that doctors and nurses did not participate in the project team. Action research ideally works best if the participants involved are those that are most appropriate for solving the problems, identifying the solutions and then putting into action the recommendation. It may have assisted the process if doctors and nurses had been part of the team. Nevertheless, the team did include the key people who were fundamental to the medication process.
- Due to the serious conditions of many of the patients who stayed in different wards in both hospitals, it is difficult to access these patients to answer the questions. The number of respondents who can complete the questionnaire is therefore limited to those who are well enough to respond.
- The cost of dispensing errors was not estimated after the implementation of LSS. An accurate estimation of medication error cost is important in order to inform whether the implementation of an intervention that focuses on reducing medication errors has been successful (Walsh *et al.*, 2017).
- The initial lack of participant awareness of Lean and Six Sigma tools and techniques created specific challenges during LSS implementation in the inpatient pharmacy.
- The roadmap has been tested with only a number of practitioners of LSS. In order to improve the validity of research, more case studies need to be executed and more people should be used for testing the roadmap with varied cultures.

9.6 Future research direction

This research raises several opportunities for future research to:

- understand the key characteristics of LSS in different hospital settings, by applying LSS in private hospitals to reduce medication errors, and then comparing the key findings with those from public hospitals.
- reduce medication errors across hospitals to save costs by employing LSS to reduce errors occurring in every step of medication use process, including; prescribing, transcribing, dispensing, administration and monitoring of the medication.
- develop LSS toolkits which are applicable to reduce medication errors in a global context.

- understand how underlying factors such as country, culture and quality of training can play a major role in reducing medication errors.
- study outpatient settings for further improvement.
- apply the roadmap in other hospitals to ensure its practical validity and enhance the application of LSS in the healthcare setting (Almutairi *et al*., 2019).
- deploy and analyse surveys or interviews to capture the higher-level understanding of healthcare staff by asking the following questions:
    - What Lean, Six Sigma, LSS or existing continuous improvement methodologies have hospitals been using to reduce medication error?
    - How many people have been trained in continuous improvement methodology?
    - What training have people undertaken with respect to quality and continual improvement tools?

The answers to these questions can be used to help project teams to understand if hospitals are familiar with Lean, Six Sigma, and LSS and whether or not there is a 'real' awareness of such tools. Project teams may also prepare an LSS awareness programme for physicians, nurses and pharmacies and/or other staff from different departments (Bhat *et al*., 2014; Antony *et al.*, 2019b). Notwithstanding, it is critical to maintain the actions outlined in the control phase in order to sustain these improvements (Al Kuwaiti, 2016). In conclusion, the calculation of the cost of the medication error is necessary for future research, in order to evaluate the impact of the intervention (e.g. Lean, Six Sigma or LSS). However, it is essential to understand the key stakeholders in order to evaluate this impact. Stakeholder buy-in is an important element in LSS project management (Sunder, 2016). The identification of stakeholders will assist the LSS project team to understand those influenced or affected by the project. The stakeholder analysis framework proposed by Elias (2016) is a very useful tool for hospital managers in the identification of stakeholders. Given the rising cost of medical care, it is increasingly important to reduce/eliminate un-necessary operational expenses which are within the control of the healthcare sector.

9. 7 Personal reflections

Doing a PhD, I as the researcher, have gained a great deal of experience, knowledge, and skills (e.g. problem-solving, self-management and communication). Prior to the research I had limited knowledge of LSS, medication errors, and research design and

methodology. Thus, I gained by reading existing literature and books to understand these key topics and I attended several workshops to improve my research skills.

Implementing LSS methodology in the healthcare sector in Thai hospitals was very challenging since I lacked the experience of the execution of a LSS project. However, before entering the field, I prepared a data collection plan and discussed it with friends who were pharmacists in Thailand. The most difficult part of doing a PhD for me was the data collection process as I encountered several problems during this stage. However, tolerance, endeavour and hard work enabled me to overcome this difficult time. When the project was completed, it demonstrated how LSS can be used to improve the medication process, reduce medication errors and save patients' lives. In this way, the results could be experienced and achieved through an empirical approach – that of action research – and not just through reviewing the literature.

During the past four years, I have focused on developing writing and oral skills and have worked on papers for publication, conferences and poster presentations. Attending conferences in the USA and the Netherlands were great opportunities to meet with researchers, PhD scholars and practitioners, to develop confidence in presentation and to gain valuable feedback from them.

The plan now is to continue implementing LSS in other sectors such as transportation (e.g. reduce road accidents) and agriculture (e.g. improve rubber process). After completing the PhD, it is important for me to disseminate knowledge gained such as how to conduct a systematic literature review and action research methodology to other academic staff. Moreover, I would like to conduct free LSS training for healthcare practitioners in Thailand.

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Appendices

Appendix A: Characteristics of Lean, Six Sigma and Lean Six Sigma included studies

Study, Year	Setting	Country	Intervention	Study design	Outcomes
Hussain *et al.* (2015)	not mentioned	USA	Lean	Toyota Production System (TPS) combined with human performance improvement (HPI) methodologis	• Eliminated expired medication to the medication units • Reduced antibiotic preparation time • Saved the pharmacy over $30,000 annually
Ching *et al.* (2013)	a Virginia Mason Medical Centre (VMMC), a 336 bed hospital with 17000 annual inpatient admissions	USA	Lean	Lean interventions were targeted to improve the medication room layout, apply visual controls, and implement nursing standard work.	• Decreased administration errors • Improved medication room layout • Minimized distractions • Decreased many injuries and deaths
Hintzen *et al.* (2009)	a University Hospital Inpatient Pharmacy	USA	Lean	Lean was implemented in the inpatient pharmacy to improve workflow, reduce waste and save cost.	• Decreased staffing requirements • Reduced missing doses, production errors and expired products
Critchley (2015)	a Headwater Health Care Center, an 87 bed community hospital	Canada	Lean	Using Lean methodology to improve medication administration safety	• Decreased the serious medication events
Printezis and Gopalakrishnan (2007)	Pharmacy at Community Medication Centre Missoula, Montana	USA	Lean	Several of lean tools were applied to reduce a high number of medications rates	• Reduced medication administration errors • 40% decrease in missing medication notifications.
Benitez *et al.* (2007)	an Alton Memorial Hospital	USA	Six Sigma	The project team followed DMAIC methodology to reduce transcriptions errors.	• The percentage of order entry accuracy has been improved by 90 per cent • Improved in patient satisfaction • Reduced workload

Study, Year	Setting	Country	Intervention	Study design	Outcomes
Chan (2004)	an Outpatient Clinic	Taiwan	Six Sigma	The project team followed DMAIC methodology to reduce dispensing errors.	• Reduced dispensing errors by over 30 per cent • Improved patient safety • Improved frontline staff productivity
Castel *et al.* (2005)	a Home-Delivery Pharmacy Service, Medco Health Solutions, Inc.	USA	Six Sigma	The project team used Six Sigma methodology to reduce process variation.	• Reduced in several types of medication errors (e.g. wrong dose selection, wrong direction, wrong patient)
Kumar and Steinebach, (2008)	surgery operation processes in US Hospitals	USA	Six Sigma	a combination of creating a service blueprint, implementing Six Sigma methodology, developing cause-and-effect diagrams and devising poka-yokes in order to develop a robust surgery operation process	• Reduced medical error rate • Improved Six Sigma quality level • Increased hospital's profitability in the long term run
Yousef and Yousef (2017)	a General Government Hospital	Syria	Six Sigma	The project team followed DMAIC methodology	• Decreased medication administration errors
Al kuwaiti (2016)	an outpatient pharmacy, King Fahd University Hospital	Saudi Arabia	Six Sigma	The project team followed DMAIC methodology.	• Reduced dispensing errors by 20 per cent
Luton *et al.* (2015)	One of the largest integrated pediatrics healthcare institutions in the USA	USA	Six Sigma	The project team used Six Sigma methodology to reduce errors in breast milk administration	• Reduced feeding errors by 83%
van de Plas *et al.* (2017)	Maastricht University Medical Centre+	the Netherlands	Lean Six Sigma	Lean Six Sigma was implemented to reduce parenteral medication administration errors.	• Reduced medication administration errors

Study, Year	Setting	Country	Intervention	Study design	Outcomes
Aboumatar *et al.* (2010)	a Weinberg Pharmacy, Sidney Kimmel Cancer Center, The Johns Hopkins Hospital	USA	Lean Six Sigma	Lean Six Sigma was applied to improve chemotherapy preparation process.	• Reduced chemotherapy preparation errors
Esimai (2005)	a mid-sized Hospital	USA	Lean Six Sigma	The project team followed DMAIC methodology.	• Increased patient satisfaction • Enhanced employee morale and better relationships between nurses and pharmacists • Reduced medication administration record errors
Nayar *et al.*(2016)	a Veterans Health Administration medical centre	USA	Lean Six Sigma	The project team followed DMAIC methodology	• Medication management improvement for dual care veterans

Appendix B: Questionnaire

Evaluation patient's satisfaction with inpatient pharmacy service in Hospital A / Hospital B

Part 1: Demographic factors

1. Gender

□ Male □Female

2. Ward name _____

3. Age

□ < 20 □20-29 □30-39 □ 40-49 □50-59 □60-69 □ >70

4. Length of stay

□ 1 – 3 day □ 4 – 6 days □ 7 – 9 days □ 10 – 12 days □ 13- 15 days

□ > 15 days

5. Education

□ Primary school □ High school □ Diploma

□ Bachelor's degree □ Master's Degree □ Doctoral Degree

6. Health status of patient

□ good □ fair □ severe

7. Have you ever received wrong medications?

□ Yes Please specify (e.g. wrong medication, wrong strength) _____

□ No

Part 2: Please rate each of the following statement

Statement	Totally disagree	disagree	Either agree or disagree	agree	Strongly agree
1. I received a correct medication, strength and form					
2. I received good quality of medication (the medications are not expiration)					
3. I received a medication in a proper package					
4. I received a correct patient name					
5. I received medications on time					
6. I received advice from pharmacists when I get the problems about the medication I received					
7. I received adequate information from nurse about how I should use my medications.					
8. I am satisfied with the nurse service					
9. I am satisfied with the pharmacists services					
10. I am satisfied with the overall inpatient pharmacy service					

Part 3: Do you have any additional comments

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Appendix C: Informed Consent Form

Informed Consent Form

This Informed Consent Form is for those who are invited to participate in the research entitled 'Lean Six Sigma to reduce Medication Errors in Thai hospitals: An action research study'

I have been invited to take part in the research on *"*Lean Six Sigma to reduce Medication Errors in Thai hospitals: An Action Research study*"*. I have been told about this research as follows*:*

- ***The purpose of the research*** is to explore the use and implementation of Lean Six Sigma to reduce medication errors in Thai hospitals
- ***Procedures,*** the participants will be asked several questions. Some of them will be about the challenges, benefits and success factors in the use of existing continuous improvement methodology to reduce medication errors. Others will be about tools and techniques which have been used to reduce such errors. Subsequently, the researcher will act as a consultant to help participants identify the problems of errors in the dispensing process and collaborate with participants to implement Lean Six Sigma, and its associated tools, to reduce such errors. During the action research process, participant will be encouraged to discuss about the problems related to dispensing errors. Participants will further reflect on the problems identified**.** Then, the participants will be trained by the researcher to understand how to implement the intervention tools. The selected intervention tool will be implemented via collaboration between researcher and participants**.** The researcher will collaborate with the participants to solve the identified problems and evaluate the outcome of the implementation of the selected intervention tools. The participants will reflect on the project and any outcomes of change to the dispensing process.
- ***Risks and discomforts,*** participants will be free to refuse to answer any questions that make them feel discomfort and to withdraw from the interview at any time.
- ***Benefits*** of the research, reduce the number of dispensing errors, increase patient safety, patient satisfaction, and an improvement in the collaboration between staff who are involved with a medication flow.
- ***Confidentiality*** of all information will be kept strictly confidential. Information will not be released to anyone who is not associated with the research.

- ***Contact information, for further information or any questions about the research project,*** please feel free to contact the principal investigators*:* Yaifa Trakulsunti, Faculty of Industrial Technologhy, Nakhon Si Thammarat Rajabhat University, 1, Mueang, Nakhon Si Thammarat, 80280, Thailand, Tel +6675377439
- **Complaints**

  On the condition that you are not treated as indicated in this information sheet, you can contact the Chair of Human Research Ethics Committee (HREC), Office of HREC

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study and understand that I have the right to withdraw from the [discussion/interview] at any time without in any way affecting my medical care.

I confirm that the individual has given consent freely.

Signature of participant.....

Printed name of participant .....

Date (Day/ Month/ Year).....

If illiterate, I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Signature of impartial witness .....

Printed name of witness .....

Date (Day/ Month/ Year) .....

Printed name of Researcher .....

Appendix 4: Participant Information Sheet

Participant Information Sheet

Title of research project:	**Lean Six Sigma to reduce medication errors in hospitals: An action research study**
Name of principle investigator:	**Yaifa Trakulsunti**
Research site:	**Pharmacy Division**
Source of fund: ***(If applicable)***	

It is important for you to know that this is a research NOT a standard procedure or treatment.

Please feel free to refuse to participate or withdraw your consent anytime.

In this document, there may be some statements that you do not understand. Please ask the principal investigator or his/her representative to give you explanations until they are well understood. To help your decision making in participating the research, you may bring this document home to read and consult your relatives, intimates, personal doctor or other doctor.

- **Introduction of the study**

A medication error is a failure in the treatment process which leads to (or has the potential to lead to) patient harm. The errors usually results from the failure of system itself rather than the individual performance of a staff. Although hospitals have endeavored to reduce medication errors by using several tools and techniques, this 'error issue' still remains. It is extremely important for the hospital to employ an appropriate process excellence methodology to reduce medication errors. Lean and Six Sigma are two most powerful business strategies for employment of continuous improvement in hospitals and are appropriate to solve specific problems. Action research methodology will be used to explore the Lean Six Sigma implementation in the hospital because it focuses on solving practical problems, interaction between researcher and practitioners who experienced the workplace from inside and creating change in the organization. The interaction between researcher and participants leads to the solving of dispensing errors in the hospitals because the researcher, the outsider who has expertise in theory and research corporates with the practitioners who have knowledge and experience in their field and understand the setting and practice being studied. In this study, the researcher will act as a consultant to help practitioners identify the problems of errors in the dispensing process and

collaborate with participants to implement Lean Six Sigma, and its associated tools, to reduce such errors.

- **Purpose of the research**

Research Aim: to develop an LSS implementation and sustainability roadmap to be followed by healthcare practitioners to reduce medication errors

Research Objectives:

1. To improve patients' safety and satisfaction through the reduction of medication errors
2. To help healthcare practitioners explore their problems and make changes in the dispensing process
3. To improve morale for healthcare practitioners

- **Procedures of the study**

Initially, semi-structured interviews (estimated 30 minutes per participant) will be conducted to capture the current state of benefits, challenges, success factors with the existing continuous improvement methodology as well as tools and techniques that could be used to reduce medication errors in the hospital. Subsequently, different data collection methods will be used through keys steps of the action research process which include observation (both participant and non-participant), a focus group, semi-structured interviews and documentary analysis. In order to identify the problems relating to dispensing errors which have occurred in the dispensing process, the researcher will observe the current process of medication dispensing to understand how medications are dispensed from the first step until the patients receive medications, as well as how people work and interact. A focus group enables the researcher to bring participants together to explore the different viewpoints and perspectives on such problems they have encountered within the dispensing process. The focus group will consist of about seven participants and will take approximately 90 minutes. The researcher will use semi-structured interviews (estimated 30 minutes per participant) to ask participants about the lessons that they have learnt from the project. The researcher will keep writing a diary to record of what happens in every phase of the action research process. The participants will be asked to keep a reflective record on their personal journal to express how they feel about the project.

The participants will take part in this research study at least six months. However, the timescales might vary depending upon the progress of the researcher as well as how well the training and data on medication errors are available within the hospital.

- **Risk and discomforts**

The participants may feel a little stressed if or when required to discuss the questions relating to the problems of dispending errors in the hospital. However, in order to prevent any potential source of harm, the researcher will remove participants' names throughout the study, thereby ensuring participant anonymity. At the end of the focus group and interview, the researcher will return of the transcript of each individual, thereby offering that person the option to remove any passages they would not wish to be included. The researcher would send an anonymized set of integrated notes for the whole group but not identifying what each individual said.

- **Benefits**

The application of Lean Six Sigma through an action research methodology could reduce the number of dispensing errors in the hospital. The predominant benefits of this study include enhance staff morale and better relationship between nurses and pharmacists, improve staff frontline performance, improve patient safety and effective communication. Furthermore, the participants can apply Lean Six Sigma to improve the performance of other processes in the hospital.

- **Compensation**

This study is a part of a PhD research programme, the participants will not receive payments for participating.

- **Confidentiality**

1. The researcher will not disclose any information gained from participants in ways that may identify an individual.
2. The participants will remain anonymous at all stages of the study by employing the ongoing use of pseudonyms in field notes, transcripts and the final presentation of the study.
4. The researcher will securely store paper data and electronic data in password protected environments.
5. All the data and information gathered from this study will be treated with care and will not be shared with anyone outside the hospital.

- **Right to refuse or withdraw**

The participant is free to withdraw consent and/or decline to participate in the study at any time before or after signing the consent document. The participants may provide the researcher with the reason(s) for leaving the study, but is not required to do so.

- **Who to contact for further information and emergency use**

On the condition that you are not treated as indicated in this information sheet, you can contact the Chair of Human Research Ethics Committee (HREC) at the office of HREC.

The participants can contact Professor Jiju Antonty (the details provided below) for further information regarding to the study.

Telephone: +44 (0)131 451 8266 **Email:** j.antony@hw.ac.uk **Address:** Room 25 Esmée Fairbairn Building, Heriot-Watt University, Edinburgh, Scotland.