A Methodology to Reduce Medication Errors: Implementing CPOE Integrated With the Pharmacy System in Riyadh Hospital

A Thesis

Submitted in partial fulfillment of the requirements

For the Master Degree in the Department of Software Engineering

At the College of Computer and Information Sciences

At Prince Sultan University

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June 2016
Acknowledgements

In the Name of Allah, the Most Graceful, the Most Merciful.

First of all I thank Allah, my God, for providing me the blessings to accomplish this research. I also would like to ask him that this project would be another tool to help in improving the patient’s safety. Then, I would like to express my gratitude to my family for their endless support, love and prayers.

Thanks for everyone who helped me in completing this work. I am deeply grateful to my supervisor, Dr. Evi I Mansor and Prof. Dr. Ajantha Dahanayake, for their guidance, support and patience. I submit my highest appreciation to the IT and medical team members from Prince Sultan Medical Military City who worked and participated in this research.

My profound thanks and appreciations to my friends for their encouragement to finalize this work, especially: Ms. Meaad Hersi and Mrs. Ghaida Al-Amro from Information Technology department in Prince Sultan Medical Military City, who offered helpful suggestions and assistance during times of doing my thesis.

Finally, my thanks to my manager Dr. Ahmed Al-Honaifan, who passed away while the thesis writing was in progress, for his advice and support from the beginning of the research.
Abstract

The rate of medication errors that affect patient safety are increasing and the medication errors are globally huge. Errors can involve medicines, surgeries, diagnosis, equipment, or lab reports (Ajami & Amini, 2013). Medication errors are the most common error. Studies show that 56% of errors is made in the drug order. Drug error prevention is improving patient outcomes (Gebhart, 2012). It was recognized that errors involved a wide range of drug classes and most commonly occurred at the prescribing stage (ASHP, 2011). In this research our focus is on computerized physician order entry system (CPOE) with CDSS feature and its impact on improving patient safety and to lower medication related costs. CPOE includes all orders for patient care (laboratory, respiratory, and pharmacy). When the CPOE integrates with pharmacy information systems, it can reduce medication errors and improve patient safety. In the healthcare organization, clinical decision support is categories in two stages, basic and advanced. Basic decision support includes Drug-Allergy, duplicate therapy checking, formulary decision support, Drug–Drug Interaction and basic dosing guidance. Whilst, advanced decision support includes guidance for medication-related laboratory testing, dosing support for renal insufficiency, drug–disease contraindication and drug–pregnancy checking (Kuperman et al., 2007). In this research, we investigated this problem and conducted a case study of the implement Clinical Decision Support (CDS) features with Computerized Physician Order Entry (CPOE) system. The study was conducted in one of the main hospitals in Riyadh, the capital city of Saudi Arabia. The system implementation is done in a software engineering context, followed software development process cycle started with requirement gathering, prototype design and development and applying evaluation testing to identify perceptions held by physicians on the benefits of CPOE based CDSS system. The study was using a combination of two methods for data collection: interviews with the IT manager, physicians and pharmacists and survey questionnaires for the physicians and pharmacists. We analyzed data using qualitative and quantitative analysis. The evaluation results showed the effective use of implemented CPOE based CDSS on preventing the prescribe medication error by alert messages. In this research, two types of CDSS evaluated, drug-drug interaction and drug-allergy interaction which are the most common used and causes most of prescribing error (Carter, 2004). This research outlines some of the challenges in implementing CDSS and recommendations for future improvements for applying an effective CPOE with CDSS are also presented.

Key words: Computerized Physician Order Entry (CPOE), Clinical Decision Support System (CDSS), Healthcare Information System (HIS), HIS improvement, patient safety, system alert, medication error.
ملخص البحث

معدل الأخطاء الطبية التي تؤثر على سلامة المرضى في ازدياد، وتعتبر ضخمة على مستوى العالم. (Ajami & Amini, 2013). الأخطاء الدوائية هي الخطأ الأكثر شيوعا، وتشير الدراسات إلى أن 56% من الأخطاء تم أثناء طلب الوصفة الدوائية. (Gebhart, 2012).

وقد لوحظ بأن الأخطاء تشمل على مجموعة واسعة من أصناف الأدوية، وتظهر غالبا أثناء طلب وصفة الدواء. (ASHP, 2011). الأخطاء الدوائية هي الخطأ الأكثر شيوعا، وتشير الدراسات إلى أن 65% من الأخطاء تتم أثناء طلب الوصفة الدوائية. (Gebhart, 2012).

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كلمات الرئيسية (مفتاحية): نظام دخول الموحسب من قبل الطبيب (CPOE)، نظام دعم القرار الطبي (CDSS)، نظام المعلومات الصحية (HIS)، تحسين نظام المعلومات الصحية، وسلامة المرضى، تتبين النظام، الأخطاء الطبية.
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<tr>
<td>IS</td>
<td>Information System</td>
</tr>
<tr>
<td>HIS</td>
<td>Healthcare Information System</td>
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<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>CPOE</td>
<td>Computerized Provider Order Entry</td>
</tr>
<tr>
<td>CDSS</td>
<td>Clinical Decision Support System</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>EHR</td>
<td>Electronic Health Record</td>
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<tr>
<td>UAT</td>
<td>User Acceptance Testing</td>
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<td>SUS</td>
<td>System User Scale</td>
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<tr>
<td>UI</td>
<td>User Interface</td>
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Chapter 1: Introduction

1.1 Introduction

There is always a risk of medical practitioners erring in the course of their practice. These errors include medical and drug errors. Medical errors are those instances when medics wrongly diagnose a disease and then end up giving the wrong or the less efficient treatment (Null, 2010).

The prescription process is one of the steps which health care providers have to go through in giving a patient the correct medication (Cohen, 2007). While in medical school, Medical practitioners acquire limited therapeutic training required in prescription. Thus, it is necessary that they learn this skill while practicing to avoid such errors.

The scenario steps for outpatient appointments are the following: The patient comes to his/her appointment and does the registration in the clerk’s desk then waiting for the call. The nurse calls the patient and enters the Physician’s clinic. The Physician should first examine a patient and collect any relevant medical history, then define the patient’s problem and specify the therapeutic objective. After that, the doctor should then choose among the possible treatments of that particular condition and for that particular patient. The medication should be both efficient and safe for the patient. The next step is to write the actual prescription, then instruct the patient on how to use that particular medication (Mcnew, 2014). This instruction includes time, amount and the condition under which they should use the drug. The last step is to monitor the patient's progress. One can ask the patient to return if the condition persists after treatment or return for a checkup dependant on whether or not the condition persists.
According most of studies, there are lots of medication errors that happen during the process of prescribing medication. These errors occur due to erroneous medical decisions (Sadock et al., 2007). There are errors of lapses, unintended errors, omissions, wrong instructions as well as poor handwriting. Some errors occur if physicians fail to make a background check of their patients' earlier treatment. Wrong or poor prescribing can lead to unsafe treatment exposing a patient to more health problems (Pease et al., 2010; Qureshi et al., 2011). It is important therefore for physicians and other healthcare providers to strictly adhere to the right prescription process based on the individual patient and the disease. Medication or prescription errors occur due to the failure of healthcare providers to follow strict guidelines as well as other reasons.

To mitigate prescription errors, healthcare providers need consistent training on prescription while practicing (Shortliffe & Cimino, 2014). There is a need to automate systems in hospitals to allow effective communication among medical practitioners. There is also the need to review and ensure consistent counter checks to ensure that doctors give correct prescriptions.

1.2 Research Background

Medication errors are a major issue in general practice and in hospitals (Velo & Minuz, 2009). Medication errors as defined by National Coordinating Council for Medication Error Reporting and Prevention are any Adverse drug events that may cause an inappropriate medication use or lead to patient harm while the medication used in any procedure in the control of the health care practice including prescribing medicine (NCC MERP, n.d.). Prescription errors are major problems in medication errors (Velo & Minuz, 2009; Xiao et al., 2010).
To address these issues, Oren et al. (2003) investigated that technology plays an important role in preventing medication errors and improving patient safety. Health information technology can improve the performance of healthcare providers and improved quality (Goldzweig et al., 2009). Health Information Systems had a great impact on the quality of care given to the patients. Health information system consists of a large number of networking technologies, electronic health records, databases for clinics, and other financial and administrative technologies that are used to store and generate healthcare information (Ngafeeson, 2014). Andersen, Rice & Kominski (2011) also agreed that the use of information technology – computerization in all ordering, pharmacy systems, use of bar coding and event monitoring could reduce the medication error rates. Since the order is directly entered into the computer, it has fewer transcription errors, increased accuracy and the order can be entered into multiple locations at the same time (Sambasivan et al., 2012).

Studies have suggested that the use of Computerized Physician Order Entry (CPOE) systems may reduce the number of medication errors (Franklin et al., 2007; Potts et al., 2004). CPOE system refers to a system where clinicians enter medication orders, medicines and tests and procedures directly into the computer system, from where it is then transferred to the pharmacy directly (AHRQ, 2014). It decreases the delay in order completion, the errors related to transcription and handwriting are reduced and error checking for incorrect tests or duplicate doses can also be provided. CPOE is thus patient management software (Roy, 2008). Many studies have evaluated the impact of (CPOE) and investigated the link between CPOE and reduced medication errors.
Decision Support System (DSS) is about processing rules obtained from storing and modeling the human expertise and knowledge for further problem solving. DSS is one of the most effective ways to reduce medication error. It integrates knowledge-based and expert-based concepts to support on deciding the suitable medication (Ting, 2011). Studies have shown that Clinical Decision Support System (CDSS) can reduce the costs and improve healthcare quality (Wright et al., 2011). Thus; Healthcare organizations are increasingly implementing clinical decision support systems, which provide physicians with patient diagnosis or recommendations helps in decision making (Kawamoto et al., 2005).

Many studies have presented that using CDSS reduced medical error and the results of some studies shown that CDSS also improved for drug preventive care and other (Lin et al., 2011). CPOE with CDSS can reduce medication error and improve patient safety because electronic order are reliable more than a hand written and the knowledge based CDSS guaranteed the integrity of order. CDSS categories into two stages (Kuperman et al., 2007). See figure 1:

- **Basic DSS** - includes Drug-Allergy, duplicate therapy checking, formulary decision support, Drug–Drug Interaction and basic dosing guidance.
- **Advanced DSS** - includes guidance for medication-related laboratory testing, dosing support for renal insufficiency, drug–disease contraindication and drug–pregnancy checking.
In this research we focused on two types of CDSS, which are the most common and causes most of prescribing errors. The other CDSS types are complicated and need more time to be implemented. As Carter (2004) the most prescribe error are medicine interaction, drug – food interaction and drug allergy. The types of CDSS covered and implemented in this research are the following (Figure 1):

- **Drug-Allergy Checking** - presents an alert when a physician orders a medication to which the patient has documented allergy.

- **Drug–Drug Interaction Checking** - many drugs interact with other drugs, causing untoward effects that are best avoided.

**Figure 1: Clinical decision support categories**
CDSS must be effective, usable and support the physicians by providing clear warning and recommendation. To achieve this, expertise should define the medical knowledge and the data needed in making decisions should be available in the CDSS. Designs should be user friendly for the physician that present and respond to the alert in an appropriate way. Some organizations buy commercial CDSS form one of CDSS knowledge-base vendors and customizes their drug medication knowledge bases even removing some alerts.

1.3 Problem Statement and Motivation

Ensuring the patient safety is one of the most important challenges facing healthcare today. The role of a hospital’s leadership is to make patient safety a priority as well as upholding their responsibility to manage programs to support patient safety by preventing medical errors (Wong, 2004). While prescribing medication is an essential order of medical practice and could improve patient safety, the method of prescribing them is complex and may cause medication prescription error.

The main reasons for the cause of medication error are patient data misinterpretation and traditionally, prescriptions are recorded on paper that causes readability and retrieval problems (Haux, 2006). Also the lack of CDSS that is capable of automatic detecting and identifying the information about drug interaction and adverse drug events. The physicians depend on their knowledge and experience in medicines, they must have more knowledge and awareness about all patient’s conditions in order to decide the appropriate treatments including the prescribed medication (Ting, 2011). Ting (2011) proposed a prototype system which integrated with data mining techniques that
generates drug interactions alert and suggestions that minimizing prescription errors and improving knowledge sharing of prescription (Ting, 2011).

Most likely prescription mistakes are interaction drug, interaction history patient, drug – food interaction and drug allergies (Carter, 2004). In attempts to respond to these issues, many studies have utilized knowledge- based, intelligence systems, and data mining techniques to provide CDSS for prescribing medication with knowledge and up-to-date information about drug interaction. Healthcare providers depend heavily on information and data of patient medical history, drug prescription order and medical expertise, which are uncertain and complex in nature. Since most of the work in the healthcare organizations are paper based, transferring from paper to computer based need to use patient data and medical knowledge in the system to support CDSS (Haux, 2006). Computerized provider order entry (CPOE) with clinical decision support (CDS) can reduce medication error and improve patient safety (Kuperman et al., 2007).

There are a few literature studies which focus on the impact of CPOE on patient safety in Saudi Arabia. In order to measure the CPOE and CDSS implementation in Riyadh, Almutairi et al. (2011) conducted preliminary studies in three hospitals in Riyadh with different CPOE systems, in-house CPOE systems and commercial CPOE systems. The goal of this study is to evaluate the CDSS features implemented in their hospitals’ CPOE. The results of their survey showed that CDSS were not fully implemented in all three hospitals.
1.4 Research Question and Objectives

1.4.1 The main research question:

What are the effective ways to eliminate errors of drugs prescriptions order?

Subsidiary questions:

- What are the required data and system components that could be implemented to incorporate patient safety during prescribe medication process?
- What are the challenges and limitations in applying the CPOE with CDSS system in health care fields?

1.4.2 The research objectives:

The aim of this thesis is to implement a system which facilitates easy prescribing of medication order entry and decision support for physicians, by studying the existing CPOE and understanding the current prescribed medication order workflow in order to measure the implementation of CPOE system with improved features and discuss the uses of CPOE with CDSS and estimate the cost-effectiveness of systems in reducing medication errors and improving the practices. The benefits of implementing CPOE within CDSS is improving of the quality of the medical prescription order by selecting appropriate drugs when prescribing medications and reducing the medication errors.

1.5 Contributions of This Study

This research contributes to healthcare information systems research and clinical practice. It was used as an aid to understand the complexity of the healthcare system. It can answer important medical questions and addresses the main question of research “What are the effective ways to eliminate errors of drugs prescriptions order?
Prototype system has been designed to evaluate all the standards noted before, beginning with a single sample patient record with one test scenario and then scale up as processes are validated and refined. A test for the revised workflows of the technology implemented to identify potential difficulties that can be avoided prior the implementation (Wipfli & Lovis, 2010; Aghazadeh et al., 2011). An Example of test scenarios alerts: Drug-to-Drug interaction, Drug Duplication, Drug-to-Disease interaction, Dose Range checking and Drug Allergy.

Implementation of in house basic CPOE with commercial CDSS based, focused on prescribing medication order in the outpatient department in Riyadh, Saudi Arabia. This research will be the first of its kind in the in Saudi Arabia. This is because most of the previous researches are from the US, European or Arabian countries and a few hospitals in Saudi Arabia have recently introduced these systems using commercially available systems.

1.6 Scope of the Thesis

The study has been conducted at the outpatient department in Prince Sultan Military Medical City (PSMMC), Riyadh. PSMMC is the Medical Services Department (MSD) of the Ministry of Defense and Aviation (MODA). The study involved physicians and pharmacists in the system’s requirements design and development phases, because they are the personnel who have to use this proposed implementation of the CPOE system. Physicians (prescribers) were involved in key decisions, Pharmacists also have the benefits of experience with an order entry system.
The main focus was on investigating the implemented CPOE at the hospital and evaluating the effective uses and how to improve functionality features in order to prevent medical errors that might result from drug prescriptions, patient history/records and medicines. For example, a physician prescribes a medication for a patient and enters it into the CPOE interface. If the patient has a medical history or even simple information that shows a contradiction to the prescription such as age, gender or allergy, it can alert the doctor to change it and make alternate choices for the patient. The system ensures that the right drug is administered to the right patient at the right time, and can issue an alert or reminders and suggest different drugs.

The functions of CPOE systems differ from one hospital to another, depending on the complexity of the system. The basic CPOE system simply offers a selection menu of drug names and doses or predefined order sets. In this study, we propose improving the CPOE functionality by providing selection and entries with reminders and alerts when prescribing medications. Order Entry has four dimensions: (a) entering information by the practitioner into a healthcare computing device; (b) functionality such as what is ordered and the prescriptions; (c) decision support directly linked with the function (for instance, duplicate therapy checking, drug-drug interaction, drug-allergy interaction, formulary interaction, alerts, etc.); and (d) integration of this function into the Hospital’s IS system. CPOE has been integrated with Hospital information systems at a later stage, including EHR and connect to the following: Clinical Data Repositories, patient information database to support retrospective Analysis and Integration/Interface Engine to connect the data repository to Clinical Workstations and departmental (pharmacy) system (Waegemann, 2002). Figure 2 simplifies the thesis scope.
When we implement the CPOE based CDSS for this research we have worked with drug information knowledge-base vendors to improve CDS functionality. Following issues need to be considered to improve the practice (Kuperman et al., 2007):

- CDS user interface: Physician should acting on alert from the same screen then returned to the prescribed medication order to continue the workflow.
- Consider an optimal and easier way to present alert to the physicians and the way for the interaction
- Not generating a huge number of unnecessary alerts
- The order of multiple alert presentations
- Who has to get the alert for example, physician, or pharmacist or both?

Integrated systems require consistent use of standards in high quality medical data. In addition, ethical, legal and technical issues linked to the accuracy, security, confidentiality and access rights to support information sharing across wide networks. This total integrated HIS is not considered within this study.
1.7 Thesis Outline

This thesis is composed of seven chapters. Chapter 1 provides the background, problems and motivation, the objectives and scope of this thesis. Chapter 2 presents the research theories and concepts derived from various works in relevant literature, including medical errors, health information systems, *Computerized Physician Order Entry*, *Clinical Decision Support* system and the challenges in *Healthcare Information System*. In Chapter 3, the research and software development methodology for implementing CPOE within CDS System is presented. Chapter 4 discusses the gathering requirements methods that were followed during this research in addition to the data and system analysis. In Chapter 5, the prototype system design and implementation is described in details. The testing process, results and discussion are presented in Chapter 6. Finally, a conclusion is presented in Chapter 7 to summarize this research study, research limitations and some suggestions for future study are also discussed in this chapter. An overview of thesis chapters’ structures is depicted in Figure 3.

![Thesis Outline Diagram](image)

**Figure 3: Thesis chapters’ structures**
Chapter 2: Literature Review

To improve patient safety, we should learn about causes of error to design healthcare systems using this knowledge to reduce common error. The effects of poor quality and medical error have impacted our lives. Throughout this chapter, we present an overview of related works and the relevant literature regarding medical errors, healthcare information systems that discussing CPOE and CDS systems, then the challenges in healthcare systems as the last concept.

2.1 Medical errors

The 1999 Institute of Medicine (IOM) report 'To Err is Human' highlighted that medical errors were the eighth leading cause of deaths in the U.S and brought to the forefront the issue of patient safety and the need to eliminate medical errors from hospitals (Kohn et al., 2000). Rates of medical errors that affect patient safety are increasing daily (Ajami & Amini, 2013) and it is costing tens of thousands of lives in U.S. (SoRelle, 2000). In a review of 110 discharge medication lists in the Augusta Mental Health Institute of Maine, 22% contained errors (Grasso et al., 2002). Causes of medication errors can involve medicines, diagnosis, surgeries, and lab reports in healthcare systems (Qureshi et al., 2011). Medical errors can occur anywhere in the health care system: In the clinics, surgery centers, diagnosis, lab report and pharmacies (Ajami & Amini, 2013). Medication Errors occur mostly at the prescribing stage (ASHP, 2011).
One of the studies has shown that prescribing errors are caused by multiple factors related to health professionals and health care systems (Qureshi et al., 2011). This may be due to poorly written prescriptions, illegible or unclear handwriting (Qureshi et al., 2011), miscalculation or errors in unit expression, faults in patient identifications, information in ordering forms, problems in memory, such as memory lapses (Bates et al., 1995; Dean et al., 2002). In addition, lack of knowledge on the part of the prescriber is one cause of medication error (Qureshi et al., 2011). Thus, many hospitals engage in efforts to prevent patient incident reports due to medication error such as dosing and conflict (Leape et al., 1998).

In Saudi Arabia, a recent study indicated that prescribing errors affect 18.7% of all prescriptions, and the impact of these errors varies from minor to serious (Qureshi et al., 2011). Another study examined the medication prescribing errors in a pediatric inpatient tertiary care setting in Saudi Arabia. This study found that the overall medication error rate was 56 per 100 medication orders. The most prevalent were presented in figure 4 (Al-Jeraisy et al., 2011).

- Dosing errors: 22.1%
- Routing errors: 12.0%
- Errors in clarity: 11.4%
- Frequency errors: 5.4%
- Incompatibility: 1.9%
- Incorrect drug selection: 1.7%
- Duplicate therapy: 1%

**Figure 4: Most prevalent medications prescribing errors**
2.2 Healthcare information systems (HIS)

HIS is an integrated, comprehensive information system that has been designed to control and manage all the hospital’s operations like financial, administrative, medical, and legal issues and provide the corresponding services (Haux, 2010). Healthcare information system can save a lot of money in the long run and the major benefits for hospitals are cost effectiveness, the efficiency of the system and safety of medical deliveries (Devaraj, 2000).

Electronic medical/ health record (EMR/EHR) systems are generally adopted in all hospitals for information system (Oh, 2015). EMR is an electronic health care information record, which stores patient information. EMR system helps to link the work of different departments in hospital. All information related to the patient is stored in the patient record (Altuwaijri, 2008).

The role of technology in healthcare is overcoming various challenges facing it and as such helping improving the quality as well as the safety of care. Among the greatest challenges of all time facing healthcare is the medication errors (Doolan & Bates, 2002). It has been shown that information technologies are viewed to have the greatest potential in helping to improve safety standards in healthcare provision, specifically in the reduction of medical errors (Clayton & Hripcsak, 1995). In the 1999 IOM “To Err is Human: Building a Safer Health System” report, the main conclusion is that the majority of medical errors do not result from healthcare providers, but rather from poor systems which must be modified and upgraded to support patient safety (Kohn et al., 2000).
2.2.1 Computerized Physician Order Entry (CPOE)

In response to the shocking IOM report, many hospitals have invested significantly to plan, procure, and implement these advanced systems, including the current focus on computerized physician order entry (CPOE). CPOE represents an important step forward for healthcare organizations because it embodies a shift from traditional, paper-based care coordination activities to automation of the order entry processes. This shift can be an agent for change, eliminating confusing or illegible handwritten order documentation, minimizing transcription errors and reducing clinical mistakes (Altuwaijri, 2008).

Computerized Physician Order Entry (CPOE) is the portion of a clinical information system that helps health care providers enter an order for a medication directly into the computer, and then the system transmits the order to the appropriate departments (Pifer et al., 2005). Implementation process has seen organizations use commercial systems. This is due to the high demand for the use of CPOE. Others have developed CPOE in their house for ease date recording and reduction of errors. National Quality Forum recommends the use of CPOE for “Safe Practices for Better Healthcare.”

CMC (Computerized Medical Orders) since August 2012 showed improvisation of CPOE. The use of alternate measure shows that more than 30% of the authorized and eligible hospitals (POS 21 OR 23) utilize CPOE. The basic functions CPOE can provide are: (a) order creation; (b) modification; (c) dictionary management of orders; (d) patient’s order profile management; (f) routing orders to various departments; (g) reporting; and (h) summarization. Overall care process can be shown as the following (Beaver, 2003):
The system uses an online network to send and receive information from one department to another. Hence, the system eliminates transcription and as such errors associated with transcription. It improves its efficiency; the CPOE is also linked with the Electronic Health Records System (EHR) to access patient history (ASHP, 2014).

2.2.1.1 Impact of CPOE in reduce medication error

According to AHRQ (2014), CPOE has been developed to address problems arising in patient medication process resulting in medication errors. Here, the physician instead of writing the order on the file, he or she places the order electronically. CPOE comprises of a system of the computer that is linked. For instance, the physician's computer is linked to the laboratory, pharmacy, radiology and other important departments (David et al., 1998). Therefore, instead of writing the order on file and handing it to the clerk to take it the pharmacy, the physician electronically sends the order directly to the pharmacist. At this point, the system eliminates the errors that might arise from poor handwriting as well as transcription errors (Morris et al., 2005). A significant number of medication errors have been associated with the poor handwriting used by the
physicians. The handwriting results in transcription errors. The doctor might also confuse patients and write an order for the wrong medication. However, the CPOE system utilizes the double check mechanism to ensure that physicians enter the correct order (Patton & Gardner, 1999).

Currently there is considerable effort to use CPOE to facilitate the improvements in delivering health care by increasing medication safety, improving the efficiency of providers and decreasing cost (Alwan, 2010). Radley, et al. (2013) conducted a study to determine the effectiveness of the CPOE system in reducing medication errors. The study was conducted in the form of random effects of meta-analytic technique. The results of the study show that CPOE is effective in reducing medication errors. Ordering medication through the CPOE system reduces the likelihood of medical errors occurring by at least 48% (Radley, et al., 2013). This number means that in the USA alone, more than 17 million cases of medication errors can be averted each year. These figures are impressive. As such, the hospital management should consider purchasing the CPOE system to reduce the cases of medication errors (Sambasivan et al., 2012).

One of the studies which compared medication errors six months before and nine months after implementing a CPOE system in hospitals reported that CPOE resulted in a 55% reduction in medication errors (Bates et al., 1998). With the addition of decision support features to the CPOE system, medication errors were reduced by 81% (Bates et al., 1999). Another study in the academic medical center in Chicago, conducted with pharmacists at a 700-bed facility, reviewed a week's worth of medication error orders and determined that, of the 1111 errors, 64.4% could have been prevented by a CPOE system (Bobb et al., 2004).
2.2.1.2 Prescribing medication order entry

In any hospital or health care institution, there are steps that are followed before the patient is given medication (Holler, 2013). The first step is normally ordering. Here, the physician selects the drug, dosage as well as the frequency. The next step is transcribing. Here, the clerk must be able to read the order and communicate it correctly to the pharmacist. The step that follows is dispensing. While dispensing, the pharmacist must check for all drug-to-drug interaction as well as the allergies among others (ASHP, 2014). The last step is always administration. Here, the nurse must receive and administer the medication as directed by the physician. As you can see, this process is long and involves multiple personnel. This phenomenon creates room for medication errors. An error might occur during transcription, dispensing or even administration (Singh et al., 2009).

2.2.2 Decision Support System (DSS) in health care

Generally, the practice that is followed is, all the information from healthcare providers (clinics, doctors, hospitals, emergency rooms, etc) is entered into the Electronic Health Record (EHR) (Berg, 2001). Through the electronic exchange, the information is then sent to local, regional and national databases. The data that flows from these databases is then used for decision support and decision-making. The Healthcare information system has the following model for information flow as in Figure 6 (Shortliffe & Sondik, 2006).
CPOE systems are generally coupled with one or the other type of decision support system. The figure 7 shows the software engineering of DSS (Mettler & Raptis, 2012).

A decision support system is an information system that uses available data into generating decisions for the user through human-system interaction (Zhou et al., 2008).
In healthcare, DSS is used in several fields; clinical or operational to serve aims such as utilization of resources or efficiency of services (Aktaş et al., 2007).

2.2.2.1 Clinical Decision Support System (CDSS)

To improve the medical care services’ quality, the practice of evidence-based medicine is being followed through the application of Clinical Decision Support Systems (CDSS). CDSSs are designed to combine patient data, medical knowledge base and an inference engine to provide case-specific clinical advice (Greenes, 2007). CDSSs are used to assist clinicians at the point of care. There are two types of CDSSs: (a) knowledge based; and (b) non-knowledge based (Berner, 1999). Doctors make use of the output of the CDSS system to determine which diagnosis would be most relevant for the patient. CDSSs help in reducing the mental workload of the clinicians and improve clinical workflows. Many a times, CDSS applications are adopted with electronic medical records (EMR), as EMRs along with CDSS applications can be used a part of CPOE and electronic prescribing systems (Eichner & Das, 2010).

(a) Knowledge-based CDSS:

The rules and compiled data are associated with IF-THEN rules in knowledge-based CDSSs. For example, for determining drug interactions, the rule applied can be, IF medicine Y is taken and then medicine X is taken THEN alert the user (Moon, 2015).

(b) Non-knowledge based CDSS:

In this, the rules are not applied and computers have to find patterns from clinical data or learn from past experiences. Doctors use them for post-diagnosis systems as they suggest patterns for clinicians to look into in more depth (Tan & Sheps, 1998).
CDSS is considered an important component of medical intelligence. It includes artificial Intelligence (AI) helped health workers in data manipulation and evaluates every order that the doctor enters. Table 1 reviews some of the current CDSS that applies AI techniques. The system is largely based on the information from the electronic patient records among others. The system utilizes the patient history, medication and so forth. CDSS uses this information to counter check all the entries made by the physician (Koppel et al., 2005). The information may be used to alter decisions made in a clinical set up. One of the decision rules are made using Arden syntax programming language that aids in encoding. For example, in Brigham and Women Hospital a laboratory technician puts an electrolyte on patient’s blood sample. The results showed 2-9 mmo/L of potassium was low. It was entered into the information system. The message obtained contained patient’s ID number and his potassium results. There are various different types of system, each with a different overarching architecture. The first is an integrated CDS system that is designed to work with other healthcare applications, which are based on a common database style of architecture. The other major type is the service-based CDS system, which are connected with interface brokers and work on a service-oriented architecture (Rahim et al., 2015). These both have their advantages and disadvantages in clinical systems, and both support integration in a different way, which means that careful consideration must be given in order to assess which is most suitable for use in the current healthcare setting.
Table 1: Reviews some of the current CDSS that applies AI techniques

<table>
<thead>
<tr>
<th>CDSS</th>
<th>Decision Support Method</th>
<th>Target</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantically Steered Clinical Decision Support Systems</td>
<td>Reflexive Ontologies &amp; Rule-based</td>
<td>Diagnosis of Alzheimer &amp; breast cancer</td>
<td>Support the generation of decision recommendations based on the data and knowledge. Maintenance of knowledge in the system &amp; handling of experience of clinical team using the system.</td>
</tr>
<tr>
<td>Bayesian Networks for Evidence Based Clinical Decision Support</td>
<td>BN &amp; Ontology &amp; Rule-based</td>
<td>Treatment of mangled extremities</td>
<td>Provide better results than purely data-based structure &amp; parameter learning approaches, &amp; existing decision support model.</td>
</tr>
<tr>
<td>A Multimodal Approach for Clinical Diagnosis and Treatment</td>
<td>CBR, IR, Ontology, RBR, fuzzy logic &amp; clustering</td>
<td>Diagnosis &amp; treatment of stress &amp; post-operative pain</td>
<td>Produce results close to the experts and better than senior and trainee clinicians. The system could be used as an expert for less experienced clinicians</td>
</tr>
</tbody>
</table>

2.2.2.2 Computerized Physician Order Entry (CPOE) with Clinical Decision Support System (CDSS)

Early implementation of CPOE system had some adverse consequences, which led to failure in providing medications in emergencies. But, with the experience in CPOE implementation, careful planning, maximizing the system’s use, all these adverse events have been averted. With the use of CPOE, the physician can provide the decision support at the time of care (Haux, 2010). The decision maker has to interact with the computer directly. Decision support helps in reducing the medication error rate and thus helps in ordering clinically cost-effective and appropriate medications and tests for the patients.
(Gardner et al., 2009). CPOE is connected with the pharmacy department, laboratory and other relevant departments in the hospital. The Clinical Decision Support System (CDSS) is connected to the whole system to alert the physician on drug allergies, medication history among other important alerts (Bates et al., 1998). CDS systems, when well implemented and designed, helps a lot in improving healthcare quality, reducing errors, increasing efficiency and reducing health care costs. When CDS alerts and recommendations are not attended properly, it poses challenges for all those who are developing, using and implementing CDSS (Davenport, 1993). According to Khajouei & Jaspers, (2009), CDSS helps in drug relations checks and provides services for the patients with reduced ADEs for about 7 to 10 times. The system aids in recognizing situations with extreme drug event and in reaching out for clinical decisions using computerized services when making order entry. In 2008, meta-analysis study showed that about 12.5% of medical errors were reduced.

2.2.2.3 Implement the CPOE based CDSS for prescribe medication order

The successful implementation of the health care system appears to be a difficult task. Software engineering for healthcare systems is an emerging field for software developers and IT specialists. Therefore, software engineering methodology that will be used for this research considers the healthcare background of the end user and the impact on the development activities (Al-Dahmarsh & El-Masri, n.d.). Implementing CDSS with the CPOE needs an approach that combines patient information with evidence of multiple types, including systematic reviews. In terms of patient safety, this must include drug-allergy interactions, drug-drug interactions, and information about suggested dosage and delivery route. To do this, the system must have an architecture that is designed to assess
the authority of the databases in question and compare them with the information given with by the physician on the CPOE system. This type of clinical decision support system has been shown to significantly improve medical prescription processes in terms of both medication error and cost-effectiveness (Ting, 2011). The CPOE system has been integrated with electronic health records system facilitate the making of right medical decisions. According to Blumenthal & Tavenner (2010), the EHR system electronically stores all the patient information. This information includes family history, patient medical history, medication history, demographic data, current medications, allergies and so forth. This information is important in making medical decisions. Hence, CPOE, through the support of the clinical decision support system utilizes the EHR information to counter check all the orders placed by the physician. Doolan & Bates (2002) add that the system evaluates the order against past medical history, previous medication, current drug-to-drug interactions as well as allergies among others. Any factor likely to affect the patient outcomes through medication is checked. Once, the CDSS finds the order appropriate and safe for the patient; it allows the order to pass successfully through to the pharmacist. In the case of an error, the system raises an alert notifying the physician and the pharmacist of the error. As such, the error is discovered before the medication is administered to the patient (Schnippera et al., 2008).

Even though it has been established that there are plenty of reasons to implement CPEO system in hospitals -mainly to reduce medical errors and provide timely feedback to physicians-, the systems implementation has been difficult; being the challenge that CPOE is by reputation hard to implement, expensive and strenuous to coax its usage by clinicians, especially physicians.
Therefore, in an effort to contrast these challenges, a two-day conference was made, as a part of the three-year research program funded by the National Library of Medicine, where experts were enticed to give their opinions on how to adopt and use this system with the best results possible for vendors, hospitals administrators, information technologies personal and clinicians. The results of the mentioned conferences were the consensus for CPEO implementation, which was that is necessary to build an Intermediate layer modeling the vocabulary, orders, orders sets, and associated behavior storage in a relational database. Being the principles of this CPOE system, where the ones employed by the 25 bed Medical Intensive Care Unit at the 349-bed acute care hospital of Denver Health a nonprofit integrated public safety net system serving the needs of Denver, Colorado and surrounding areas.

This system is currently alive in the MICU having about 60,000 orders entered every week, and 400 physicians and nurses effectively trained to use it. The reason why this system works so well at the Denver Health is that the clinical orders related to order details are constantly reused. This translates into orders being represented as closely aligned to the physicians desires, and there are order tabs for nursing, diagnosis & therapy, and also medications with subcategories such as chemistry, hematology, and microbiology for the laboratory (Hillestand et al., 2005).

Development of the order sets at the Denver Health has been possible due to the ability to nest subordinate order sets within larger order sets. They use the orders as both stand alone and to incorporate in other ones. So far they have composed around 20 orders sets for the MICU in order to use this technology; many of which are to be reused by the other departments set to start employing CPOE. By analyzing this case, it seems the
usage of an intermediate order design pattern layer for CPOE has been more successful when building complex orders and order sets for the IT staff, displays orders becoming more physician friendly and providing an improved display and search experience with a method that facilitate a better practice of order sets.

In order to extend the usage of CPOE, Denver Health has recurred to the basic functions which allow the end user to find the words or problems he or she might be looking for more quickly; to increase the searchability of studies and procedures. In order to do this effectively, Denver Health proceeded to upload common laboratory, and radiology synonyms into the engine, and to do so they asked laboratory and radiology staff members because they are the ones who have more experience answering questions related to the names of specific studies and procedures. Thanks to this one-time process, the complaints of “I can’t find…..” were significantly reduced, although the synonyms loaded only represent 5% of the ones used on these departments.

So far Denver Health hasn´t integrated CDSS into its CPEO system and it doesn´t seem to be in any hurry to do so, but the implementation of this support system could greatly benefit their diagnostic ratio. CDSS combined with what Denver Health has already accomplished would certainly provide the accurate way in which the physicians of this center could review the diagnostics given by their colleges and by doing so, reduce the possibilities of a mistake in the mentioned diagnostics, as well as in medication cases with the nurses.

Studies elaborated not only in the US, but also in countries like Korea, have shown that CDSS has been fundamental in the increase of user satisfaction, especially
when oriented to medication/drug usage. The role of CDSS can help in detecting flows in care provided to heart patients and lead to improvement. For instance, the use of CDSS can lead to discovery of abnormal cholesterol levels or blood pressure in the red text so that smokers can be referred for cessation medication and the effects of smoking investigated. CDSS is linked to a provider order by CPOE has reduced adverse drug reactions, enhancing the drug safety use.

However, while the reduction of medication errors before and after CDSS has been proved, the employment of said tools compared to other electronical medical methods is still lacking. This can be attributed to CDSS still being in the early stages, as well as to its use insufficient, and the development and utilization for prescriptions and dispensing of medicines limited.

According to the study realized, in order for CDSS to be effective in reducing medication errors, its key users have to be satisfied. There are a number of factors which are key in setting up a successful CPOE system based on these architecture features. The first is that they must be fully integrated so new patient data does not have to be entered into the system (Rahim et al., 2015). This helps to improve the clinical decision support offered by the system, and prevents medical error that can occur in information transfer between systems. Kaushal & Bates (2002) note that reducing clinical error is the primary goal of these CPOE systems and therefore must be the defining factor when assessing which is the most suitable for the task at hand.

The satisfaction critical success factor (CSF) for CDSS has been recollected in many studies such as DeLone and McLean, with the subdivision success measures of
information systems parted into six categories: 1) system quality, 2) information quality, 3) user satisfaction, 4) usage, 5) individual impact, and 6) organizational impact. Later Van Der Meijden examined the determinants of success of inpatient clinical information systems using DeLone’s and McLean’s work. And finally the performance of the CDSS for medication was analyzed in 38 hospitals by using the DeLone and McLean model of information system (DeLeon & McLean, 1992). Both systems for quality and information quality were found significantly influenced by user satisfaction and therefore have been approved. However, the findings enlisted were based on responses from pharmacists, not including doctors responsible for maintaining drug safety, which makes the argument of CDSS usage in hospitals somewhat more challenging.

2.2.2.4 Clinical Decision Support Systems Alert

Calloway et al. (2013) describe the several types of system alerts given by CDSS. Among them is the allergy alert. For instance, the patient might be allergic to penicillin. Hence, upon the physician ordering penicillin, the system raises the drug allergy alert. CDSS also checks the drug-to-drug interaction (Doolan & Bates, 2002). The interaction between the biomedical and physical of certain medications can result in adverse events. Hence, CDSS reviews the interaction of various drugs in the patient system giving alerts where a problem is detected. The system also considers the demographic data such as age and gender to ensure the medication ordered safe and efficient for that specific patient.

The EMR system includes the CPOE screens and the CDSS are used for prescriptions and preventive care. One such example of how CPOE screen along with CDSS works is shown below:
In this sample above, CDSS screenshot is shown. An active reminder is indicted by the red “PP” flag in the important information screen. By clicking on the red marker section, the recommendation is shown. If the physician agrees with the recommendation, he would order that. Reason should be mentioned in case of non-acceptance of the recommendation (Morris et al., 2005). CDSS displays alerts in several ways, such as a pop-up warning. The pop-ups are interruptive and as such the physician can note them immediately. The other method is through highlighting of relevant patient information. For instance, the system might highlight the age, gender, allergy, past conditions and current medications to try and help the physician make the right order for the patient. The other common method used is the provision of links. These links are created automatically and lead the physician to points where he or she can access relevant patient information.
information. Some of these links might be to the EHR patient portals and so forth (Calloway et al., 2013). However, Greenes (2007) notes that sometimes some of these alerts might be too many and also interruptive. The alerts, especially the pop-up alerts can be disruptive and as such affecting the physician's efficiency at work. Moreover, there are cases where CDSS raises false alerts. This problem, therefore, affects the effectiveness of CDSS in improving the safety and quality of medical care (Koppel et al., 2005).

2.3 Challenges in Healthcare Information System (HIS)

Though the HIS provides a huge potential and the opportunities to transform the healthcare sector, there are many challenges currently being faced which are evident. Firstly, the adoption of the information technology in healthcare has really been very slow and lags behind major industries of IT by almost 10-15 years (Goldschmidt, 2005). The resistance to use information technology by healthcare professionals and the failure in HIS implementation is also one of the major challenges in healthcare. The challenges may vary from technical issues, issues in healthcare settings, regulatory environment, and system users’ settings. Some of the barriers to the adoption of IT in healthcare in U.S as provided by Blumenthal (2009) are: the adoption rate by doctors and hospitals is very less, issues with privacy and security, medical errors committed (Blumenthal, 2009). Commitment to quality is a critical factor in which healthcare personnel must commit. The use of systematic process ensures that a database related method is used to keep track of the medical records (Khajouei & Jaspers, 2009). It is recommended that trained and informed personnel should only be allowed to update the data. Further, there is the need to provide sufficient training. The users can be trainer of the trainees.
There are several requirements which need to be considered when dealing with healthcare software, such as security, reliability and performance. Data accuracy and availability is also a critical characteristic (Al-Dahmesh & El-Masri, n.d.). The development of requirements that include clinical decision support and workflow configuration may increase the success of CPOE implementation. The most advanced implementations of such systems provide a real-time clinical decision support such as drug and drug-allergy interaction checking and duplicate therapy warnings and dosage (Pifer et al., 2005). The deployment of health information systems is especially challenging for Saudi hospitals because of high implementation cost, technical complexity, lack of information and communication technology (ICT) infrastructure, and lack of well-trained employees (Altuwaijri, 2008). Upon implementation of the CPOE system, the hospital must ensure that they have resources that can support the facility. Notably, the decisions made must be based on the cost benefit analysis founded on the scope. In this way, decision integration can be implemented. The current context has shown relatively low response in the implementation of the system (Walshe & Smith, 2011). HITECH Act 2009 is focused in ensuring that the incentives provided meet the threshold of rendering meaningful health care.

Medication errors are expensive and in some cases harmful to the patient. For that matter, it is the duty of every health institutions’ management to put measures into place to address the medication errors. Some of the medication errors do not arise from arising from individuals, but rather a system that is already in place. Some other factors such as the shortage of staff further increase the chances of medication errors. For that matter, organizations require an effective solution: CPOE and CDSS (Greengard, 2013).
The hospital administration can also conduct a survey to obtain the feedback from physicians regarding the CPOE System. The survey would be best carried out in the form of an interview. The major topics covered include ease of using the system, time and effectiveness in reducing medication errors among others (Bates et al., 1997). The hospital administration can also conduct a survey to obtain the feedback from physicians regarding the CPOE System. The survey would be best carried out in the form of an interview. The major topics covered include ease of using the system, time and effectiveness in reducing medication errors amongst others (Bates et al., 1997).

2.4 Summary

Healthcare information systems provide high reliability, increased readability, reduction in medical costs and increases the overall quality of the healthcare (Blumenthal & Tavenner, 2010). The government should invest in technology in healthcare to help achieve desired outcomes (Anderson, 2006). The implementation of CPOE surely ensures the safety of the patients. CPOE is also recommended as one of the 30 “Safe practices for better healthcare” by the National Quality Forum. In conclusion, medication errors are a huge problem in health care. However, the CPOE system seems to be one of the most solution used to solve this problem as the previous relevant studies. CPOE allows electronic entry and the sending and receiving of orders. This reduces the chances of medication errors by around 48%. CPOE is connected to CDSS, which counter checks all the entries based on the information from EHR and other areas to ensure safety of the medications offered to the patient.
Chapter 3: Research Methods

This chapter describes the research methods used in this study, including the ethical issues. In this project, both qualitative and quantitative methods were followed to implement the CPOE system, used to support the research validation from their feedback and measures the usability. The results of these evaluations should be used to further refine and improve the CPOE system.

After approval is received, we get approved to create a related project, the IT department creates an E-prescription project under the Project Management Office (PMO) division to implement the system and achieve the research objectives. The PMO assigns the Project manager responsible for this project who request the resources from the development division. They have assigned the required team under E-prescription project. There are five major team roles in addition to the project manager: business analyst, systems analyst, database admin, developer and testing expert.

3.1 Ethics in Research

Ethical permission was obtained from the PSMMC hospital and Information Technology (IT) department in order to conduct this study. Questionnaires used by the specialist needed in this research (physicians) will be kept for studying the issues. Due to the hospital policy, all data used to test the cases (patient information) will be kept confidential.
3.2 Research Methodology

This research followed the systems development life-cycle, the set of activities which encompass requirement gathering, system design, building prototypes and evaluation. These activities are interdependent to each other. The output of the previous phase is the input of the next one (Balaji & Murugaiyan, 2012). Requirement gathering phase focus on data collection and the requirements which used in the next phase: system design. System design shows the database and user interface. Building prototypes describe the function codes used. The last phase is evaluation and shows the system evaluation process and the results.

In order to build a prototype system with the same CPOE characteristic and CDSS as a deliverable for the decision making process for a PSMMC, a rapid prototyping software development life cycle model has been considered to derive this software. Prototyping is a simple system showing the main functions of the proposed system. Prototyping have more user involvement and allows to interact with a prototype and provide their feedback and specifications. When the final software is developed, it is more likely to satisfy the users. This type of prototyping uses little efforts with minimum requirement analysis to build a prototype (Sabale & Dani 2012). Once the actual requirements are done, the prototype is discarded and the actual system is developed with a much clearer and a fuller understanding of user requirements.
3.2.1 Requirements gathering and Analysis

This phase is the main focus of the end user and project managers. Requirements gathering methods were used for implementing the system are both, qualitative and quantitative using an interview and questionnaire. Several interview sessions were conducted with a team of physicians, pharmacists, IT staff and CDSS vendor who participated to set system requirements. IT staff is responsible for understanding the technical aspects, CDSS vendor provides drug medication knowledge bases required for different CDSS alert scenarios cases, but physicians and pharmacists are best suited to determine how the CPOE system can be implemented. A set of questionnaires were distributed to physicians and pharmacists regarding the challenges that may be encountered during the use of CPOE and have their suggestions on improving the previous system before that helps us there on system implementation. After gathering the requirements, the information gathered is analyzed. Qualitative content analysis used to
analyze the interview and pretest study with “Question pro” program used to analyze the questionnaire. The results documented in the business requirement document to be used for the next phase.

3.2.2 Quick Design

The early design of the CPOE system helps in defining overall system requirements, database tables, database schema, uses case diagrams and the user interface of CPOE with CDS for detection errors and alerts. Based on the requirements gathered from the previous phase, the process started when the physicians and pharmacists were both interacted with the system, although the physicians have more interaction. Then, the physician entered the patients’ data, prescription information, and receive alerts. The pharmacist received the prescription for the medicine despising process. Next, the database mapping was done with drug medication knowledge bases and database from the CDSS company. Overall, the early system design specifications help in building the prototype system in the next phase.

3.2.3 Building the Prototype

This is the main phase for the developer for coding. E-prescription order pages were created and integrated with the medication error detection components. CDSS Company provides us with the application programming interface (API) for building CDS software in addition to the database files needed, the API software modules were designed with the following software system objectives:

- Ease of implementation
- Performance
- Easily updatable
The test patients and test medication orders were developed in order to evaluate a CPOE system’s ability by detecting prescribing errors in different decision support categories to evaluate the system efficiency.

3.2.4 Evaluation

After the codes were developed, an expert tested the system in order to check and remove any errors or bugs, and tested against the requirements by end users to ensure that the system is meeting the requirements need. In this phase, test cases scenarios with User Accepting Testing (UAT) were conducted. Physicians evaluated the improved features of implementing CPOE in. Physicians were the key central players in the decision-making process, as a prescribers. They were involved in the initial efforts of including designing, workflow, system analysis, testing. Test cases scenarios designed to test it with selected patients in order to check the results. The orders and test scenarios took as following steps:

- Selection of specific decision support category that needs to be tested
- Testing patients and orders given
- Checking the results, error detection and alerts
- The order set will be periodically reviewed and revised and modified
- New orders and scenarios introduced to maintain the validity and currency of the test

The developer team evaluated the specific scenarios and alerts response. List of test patients with various medical conditions were downloaded in the CPOE testing environment, then the potential users provided a series of test orders entered and tested with the patients’ existing scenario and setting. The CPOE system’s responded to the entered orders and then reported through the evaluation system.
3.3 Prince Sultan Medical Military System Case Study

A case study method was selected as it is useful for gaining a rich understanding of the research’s context (Saunders, 2011). Using case studies to build theories is considered one of the best methods to do this (Eisenhardt & Graebner, 2007). In this study, a case study of implementing CPOE within CDSS and estimating the cost-effectiveness of the system in reducing medication errors. The study has been conducted in an outpatient department in Prince Sultan Medical Military City (PSMMC), which is formally called Riyadh Military Hospital. PSMMC is one of the largest military medical cities in Saudi Arabia.

The hospital services are served through the main hospital and 18 outside centers/clinics in Saudi Central Region. PSMMC has its own in-house Pharmacy system and ongoing doctor portal system in hospital’s internal site. The system is partially implemented and started to be used in three selected outpatient departments in the main hospital. The doctor portal goal is to build CPOE for patient history and electronic order for all departments, Laboratory, Radiology and Pharmacy. The pharmacy part which is the electronic prescribing medication order is still not implemented. In the doctor portal the physicians can retrieve the patient’s previous visits and enter the new diagnosis with treatment plan requests.

The study targeted only physicians and pharmacists because mainly they are the most personnel that have a huge part in the system.
3.3.1 Current workflow for prescribing medication order:

Prescribing medication order is paper based, when the patient came to his/her appointment and entered to the physician’s clinic, the physician examines the patient and makes the treatment plan, if a prescription is needed he will fill the prescription form and give it to patient who will go to the pharmacy and collect his/her medication. The workflow is as follows in Figures 10 and 11:

![Patient's visit workflow diagram]

Figure 10: Patient's visit work flow
3.4 Summary

In this chapter we outlined the ethics in research and the study research methods within the systems development of a life-cycle which we followed with a brief for each activity. We have also described the PSMMC system case study.
Chapter 4: Requirement Gathering and Analysis

This chapter will discuss the research collecting approach that was followed during this research. The chapter will describe in details the user requirements activities, gathering methods used, data analysis and system analysis.

4.1 Requirement Gathering

4.1.1 Choosing requirements activity

In the software engineering process, several methods are widely used to elicit requirements, such as interviews, task analysis, and observations (Hadar et al., 2014). Each type of method has different goals and provides different information.

This research applied a research approach combination of both qualitative and quantitative methods to answer the research questions and achieve the research objectives (Baxter, 2015). The main method used is the interviews and it is the most common method which helps the analysts extract the requirements from the stakeholder in case study (Hadar et al., 2014; Driscoll 2010). A questionnaire method was applied in order to understand the challenges that may be faced during the use of CPOE.

Then, a proposal was prepared, together with the approvals needed and resourcing the participant (Baxter, 2015). The IT management has to decide on buying commercial knowledge base CDSS company (vendor), or create their own business rules database which will take longer time. They were agreed to select one of the vendors that the hospital was studying to contract with them before. The IT department initiating an E-prescription project with a team consisted of project manager, analyst, database administrator, developer and tester.
4.1.2 Gathering requirement methods

This section shows the details of two types of methods used, interviews and questionnaires.

4.1.2.1 Interviews

The analyst performed face-to-face semi structured interviews with project stakeholders using an English language. The analyst has domain knowledge prior to the elicitation process: IT and Medical background to encourage communication with the stakeholder and understanding their needs (Baxter, 2015).

Participant

A total of 6 interviews were conducted. The sessions were conducted with two physicians, one pharmacists, two from the IT manager and the CDSS provider. The study took place in the IT department meeting room for the physicians and pharmacists with all physical requirements needed such as a table, board and PC. The table in the middle front of the PC smart screen, and the board in the corner for further information needed to explain clearly. The other place was at the employee offices for the IT management.

Procedure

The interview sessions were conducted using semi-structured methods. The analyst uses a prepared set of questions to gather requirements from end users. It is formal individual face-to-face direct interview. The users to be interviewed was chosen purposefully based on their experiences in this field. Each interview was done on different days and takes around two hours. The main topic has been discussed with all interviewees; it becomes more depth based on the discussion during the interview and on the interviewee role.
During the interview, we begin by assuring the confidentiality of information for research use, and introduce each other. Then the participants were asked to share their experiences of the workflow of prescribing medication, available systems used with functional details and to note what the advantages and disadvantages of CPOE were. At the last point taking their recommendation to implement CDSS and improve the CPOE system.

Empty papers were used to design their needs of different scenario screens for E-prescriptions, fields required and alert messages appears. The board and the PC in the meeting room help to understand the design during brainstorming. Each interview was approximately one hour in duration. The following are interview details for each interview role group:

**For IT staff**

Two of the interviews with the IT managers have been conducted in order to understand and study the hospital systems, CPOE and Pharmacy system. The main questions were the following:

- If there is any planning to build complete CPOE system?
- The CPOE type used is commercial or in house system?
- What are the required system components that could be implemented to incorporate patient safety?
- What are the challenges and limitations in applying the CPOE in health care fields?

The IT already started to develop CPOE system for physicians, but still used by some outpatient departments such as Chronic disease and ENT departments, their
strategy to be applied and used in all departments in PSMMC while they complete the all CPOE and related electronic orders. For that we decided to design the e-prescribe medication page in prototype system have similar design with doctor portal used in hospital. This prototype has a simple design with main functions needed (“Log-in”, “Patient Information” and “Prescribe Medication” order that linked to the e-prescribe medication page). All the development phase will be as a prototype system in a test environment. After the interview session with the IT management, they suggested us to contact the CDSS provider to have a technical detail on CDSS implementation.

**For CDSS company**

We interviewed this company and discussed how we can integrate CDSS with our CPOE and what is the data needed from IT to program the code and mapping the database tables with their knowledge base database.

After the discussion meeting, we have an agreement to sign an evaluation scope contract (trailer) signed by IT management to support this implementation with two types of CDSS from eight types they served and within 65 days time frame. The two CDSS types chosen are drug – allergy and drug–drug interactions, since those two types are our focus in this research. As we mentioned before, these CDSS types are the most common used and causes most of prescribing errors in addition they easier to be implemented.

- **Drug – Drug Interaction function** - To alert the physician of a drug interaction between the prescribed drug and a drug prescribed in the prescription list. Or interaction between the prescribed drug and a drug in the patient’s history profile.
• **Drug Allergy function** - To alert the physician of current allergies between the prescribed drug and the allergies in the patient’s allergy list.

**Physician**

The information about current prescribe medication workflow and its processes, services products and resources have been collected and discussed in details. The main question was:

• How you prescribe medication order for the patient and what the systems are used?
• How we can simplify the electronic order way and eliminate medication error?
• If CPOE can improve patient safety?.

Although, a number of interviewees suggest different ideas as a solution to the defined problem based on their experience and what the main information needed in addition how they will interact with system alert.

**Pharmacist**

We interviewed the head of the pharmacy department. We discussed the pharmacy side while their process is medicine dispensing such as:

• What kind of system they used?
• How did they receive the prescription?
• What is the workflow for medicine dispensing?
• How they can check if there is a prescription error?
• What is the most medication error types they faced?
They would like to have an intelligent system or at least received a prescription without need to double check any errors manually. With such system they think they will be saving more time and improve the quality and reduce the errors.

4.1.2.2 Questionnaire

The second method used for this research is quantitative and qualitative, for open questions using a questionnaire. A set of questionnaires were distributed to 25 doctors who are using the existing CPOE system with 9 pharmacists in order to have their feedback and study the challenges they may have faced and the CPOE improvements recommended. The questionnaire includes three categories, demographic, medical practice with multiple choice questions about the CPOE and CDS systems. Each participant was asked to rank related questions and open questions for their suggestions. The first part about gender and age, then his/her role and the main questions about their satisfaction of using such system and how they rate the effect of the system in some criteria like reduce patient care errors, and quality improvement by integrating CDSS. Finally, with what the challenges may face and their suggestion. The questionnaire form is in Appendix A. The questions were prepared depending on some CDSS paper references about CDSS Greenes (2007). The questionnaire was designed and developed depending on the relevant literature and by the following steps:

- Selected the appropriate characteristics to answer our research questions and addresses our objectives by understanding the research and reviewed the literature carefully.
- The sample participants were the physicians and pharmacists and the size between 20-30 responses.
- Undertaking the research by using the correct terminology and an English language.
Reliability is established using a pilot test by collecting data from 20-30 subjects not included in the sample, but since it is a basic quantitative questionnaire as feedback forms with small sample size. Piloting is only really needed for large or complex questionnaires, and it takes significantly more time and effort. To do a pilot, we need to test all the questionnaires steps from start to finish with a reasonably large sample. For our questionnaire, we have used “Pretest” concept. When we finished designing our survey questionnaire, we have selected five people from our target group to pretest it. Four physicians and one pharmacist asked to complete the questionnaire one at a time. While they are completing the questionnaire they tell us what comes into their mind and we noted everything regarding unclear points and the formatting layout.

Then when all the testers have completed the questionnaire, we reviewed our notes. At this point it was clear what the major problems were so the questionnaire improved to address those problems. We have used survey design software (Question pro) to design and analyze the results.

Questionnaire forms were distributed to a group of physicians, 23 from general clinic and 2 from quality department, and 9 pharmacist. We interviewed them and start with small chatting about electronic system and difficult to use, then distribute the questionnaires. For this session, participants spend approximately 10 to 15 minutes to complete the questionnaire.
4.1.3 Data Analysis

At this stage, requirements are examined to review and resolve any conflict. The information elicited during this process has to be analyzed and modeled.

For the interview, the analyst conducted a paper transcription. A total of 5 interviews hand written were transcribed with additional noted had been taken in a word document. The Appendix A includes all transcripts of the interview. Qualitative content analysis used to analyze the interview content, the goal is to identify important themes or categories within a body of content. The analyst for this project is qualified to do this analysis since he worked in this area for more than 7 years and aware about the research question and the research objectives. In addition, he read a publication in the same field which have done similar work, to see what the standards we have used. To start, he read and annotated each interview transcript and created the initial coding process. During the coding process, word document used. The texts were unitized and concepts were highlighted and labeled by adding comments and bookmarks. The analyst labeled the relevant sections, the label about concepts and process and what he thinks it is important. Three round coding done by the same analyst. He repeats and examines the initial code again and combining two or more codes and themes. Then “DocTools ExtractData “add-in used to extract each theme and related content to the excel sheet table.
Figure 12: Coding process steps

The analysis done for each transcript. At the end, all related themes connected together as table 2. “Primary themes” are mentioned by the most individuals.

Table 2: Primary themes and sub-themes recorded from 5 end users’ interview

<table>
<thead>
<tr>
<th>Primary Theme</th>
<th>Sub-themes</th>
<th>Supporting from interviews</th>
</tr>
</thead>
</table>
| 1. Information needed to order (in screen) | • The doctor can browse the patient drug profile (all drug prescribed details), lab record(requested test and result) and radiology (in1)  
• display all patient history record (in1)  
• using Mainframe for retrieving all patient information (in2)  
• access patient drug profile entered by pharmacy department checking all drugs, old and new one and drug status (in2)  
• The screen about CPOE and all past patient visit details and the order services: Radiology, Laboratory and Pharmacy (in2)  
• For the patient information, we should access the patient profile in mainframe just for retrieving the information(in3)  
• CPOE that should contain all information and e-requests needed (in3)  
• Drug code, drug name, drug dose needed, the route, frequency, duration and can write any comments related to this drug.(in3) | 5 of 5 end users |
• one place contain all patient information needed in a clear way. Site or list contains all drug interaction rules (in3)
• have to check all the drugs for patient history and the current drugs he have (in4)
• We enter the drug name using drug code or drug generic name. Then complete the instruction by filling the route, dose, frequency, and duration (in4)
• browse clear information with different tabs, the entries will be dropdown list if possible, contains recommendations and automatic validation. (in5)
• writing paper contains drug name and prescription details, all other info needed for diagnosis and vital signs. In addition, the doctor detail
  • the doctor writes the treatment field need, the subjects, symptoms, tests and prescribe medication and write all treatment plan (in1)
  • The doctor check patient drug profile from current system then prescribe the medication needed by write it with medication details (drug name – dose – rate – frequency and any comments) on prescribing medication paper form (in1)
  • review the drug history for particular patient then write it on the consultation paper (in2)
  • information of subjective, objective, diagnosis and assessments stored in patient file by sending all consultation paper to the medical record department (in2)
  • physician start examining patient decide what is the diagnosis and enter it in the encounter form and enters the request with another special form for each department (in2)
  • physician using paper based “Encounter form” to write all the treatment needed and the prescription (in3)
  • received the patient from nurse after he do the registration at the clerk’s desk and waiting for the call. The nurse taking vital signs of Patients (in3)
  • physician ask the patient about symptoms, to diagnose his problem and do the treatment needed. If prescription needed, they can review the patient profile in mainframe to check the drugs and the write the order in paper request and give to the patient (in3)
  • the patient has the responsibility to back to the doctor in order to modify the prescription (in3)
  • We are open the mainframe from our PC’s to Browse the patient information needed (in4)
  • we are depending on paper prescription request (in4)
  • We examine the patient and request the order needed, which includes the prescription order (in4)
  • We write it manually in the prescription order paper (in4)
  • If there is any modification needed, the patient return to us to change it. (in5)
• 5 of 5 end users
### 3. Detecting Error

- Select right drugs for the right diagnostic by implementing more rules and alert for high risk medication or allergy (in1)
- We started select one of the CDSS providers (in1)
- Has all important intelligent rules, correct decision and recommendation alerts, fast and accurate error detect (in1)
- Implementing the CPOE by Allergy store checking Drug interaction by implementing the CDSS (in2)
- Can integrate and have the correct recommendations and alerts (in2)
- The harmful error is patient pregnancy interaction need drug interaction, but what are not detected usually is the drug drug interaction (in3)
- Drug interaction rules implemented help in decreasing the errors and improve patient safety (in3)
- Check all the patient demographics with the new drug (in4)
- Prepare our self to learn all drug interaction rules to avoid any errors might happen (in4)
- There is an intelligent applications has these rules and alert the doctor if there is any error detected (in4)
- Assures to centralize all accurate patient information needed and can prevent any error might happen then improve patient safety (in4)
- Drug–drug interaction because it is difficult to detected and other types such as drug–dosing and Drug–allergy interaction (in5)
- Drug interaction not easy detected and taking long time to check the all prescription against all drugs interaction types (in5)

### 4. Problems / Challenges

- There are three main challenges: Integration between system Create rules for knowledge base and I think we will face challenges in Physician readiness (in1)
- The system used by three departments and implement the log-in page and the main screen for diagnosis entry. There are some orders implemented such as Radiology request (in2)
- Still the physician using paper for some orders not implemented yet in the CPOE (in2)
- By the CPOE the users can minimize the hand writing error and Loss of patient medical records (in2)
- Some physicians prefer not to use CPOE they prefer the paper based, integration between system, development cost and central sterilization services department (in2)
- Errors caused because of lack for the information that could effect on the prescribed drug we have (in3)
- There will be resistance from some doctor to use an electronic device and writing form keyboard (in3)
- Doctor should be aware of all drug interactions (in4)
- Drug Allergy or Drug–food interaction, if the doctor didn’t check the patient allergy or the patient’ allergy

- 5 of 5 end users
itself not updated. Also Drug – drug interaction and many types (in4)
- these error reduce the patient safety and quality it may casus patient die (in4)
- the prescription reviewed by the pharmacist (in5)
- If any changes needed, we contact doctor by return the prescription with a patient or by phone to change the drug to other one (in5)
- We did it usually depend on pharmacist experience and upon the pharmacist's knowledge (in5)
- there is a kind of drugs can be prescribed by consultant doctor, depending on his specialty, so we need to control this issue electronically rather than handwriting (in5)
- CPOE contains intelligent mechanism and display all patient history record (in1)
- The main system is HIS (Health Information System) with patient information database, LIS (lab Information System), PIS (Pharmacy Information System), Common Clinical Data Base, ICD 10. HIS (Health Information System) with patient information database (in1)
- There is an intelligent rules /recommendation alert or it is clinical decision support system that can help the doctors during patient’s treatment (in1)
- applying CDSS will decrease the error and improve patient safety (in1)
- Provide easy access for all updated patient’s data from all departments (information needed and results), Usability : ease of use, secure system (in1)
- developing log in screen for doctor by user name and doctor code with three main parts: chart (sub, obj. diagnosis and allergy), CPOE for ordering which will be for lab / rad/pharmacy and patient history (in2)
- , there is a sub systems to implement CDSS Company can be integrating, they request the all medication database in the pharmacy department, and then they map it to the cdss rule they have (in2)
- The CPOE should support HL7 msg so can communicate with all departments systems and integrated with centralized database (in2)
- the doctor portal developed which contain basic information about patient and electronic order (in4)
- Pharmacy system that connects the patient profile (drug info) and drugs system for the drug stock and all drugs managements (in5)
- The patient takes it to the pharmacy department to dispensing the medication (in1)
- patient takes it to pharmacy to receive the medication (in2)
- The pharmacy updating patient file from their side (in2)
- The Pharmacist should detect the error, depending on pharmacist experiences in this field (in2)
- After the pharmacist checks the request, who check it
To assess the reliability of the data, the analyst repeated the codes three times to achieve these results. He codes all the data, then, after lapse of time (two weeks) he re-code all the data and after further two weeks re-code some part of the data. The reliability score of the inter-coder achieved by the same analyst, but at different points of time and calculated by the following metrice:

- Percentage of reliability = \[
\frac{\text{Number of Agreements}}{\text{Number of Agreements} + \text{Number of disagreements}}\]*100

For example, to assess the reliability of the first theme, the first inter-coder check procedure was calculated as the following:

- Reliability = \[
\frac{3}{3}\] *100 = 100% , the results of compared for agreements showed close agreement on the basic themes.
For the questionnaire, the analyst stores the answers and analyzes the results by “Question Pro” program (Figure 13, 14, 15, & 16).

For the satisfaction of using CPOE (especially from the physicians) we observed that they have somewhat satisfied to use it as seen in Figure 13.

![Figure 13: The result of overall level of satisfaction using CPOE](image)

From their rate results on the CPOE attributes, we can notice that “Order entry reduces patient care error” had strongly agree as described in Figure 14.

<table>
<thead>
<tr>
<th>Question</th>
<th>Score</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order entry reduces patient care errors</td>
<td>3.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order entry has a negative impact on patient care</td>
<td>2.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order entry improves the safety of care I provide</td>
<td>3.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order entry gives me the information I need to write better orders</td>
<td>3.68</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order entry improves the quality of patient care</td>
<td>3.94</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Figure 14: Rate results on the CPOE attributes](image)
In order to investigate in which stage usually the most common error happens, we outlined three most order requests, and the results show that most of clinicians agree that most error may happen in the prescribe medication order stage. Prescribe medication order had 62.68%, which means there is a high need to eliminate the errors in this order process.

![Pie chart showing error distribution]

**Figure 15: Where the most errors may happen**

To investigate what are the challenges of using CPOE, we get the following result which concludes that both “order entry system is not easy to use” and “order entry slow me down” considered as big challenges.
Figure 16: The challenges of using CPOE

Their responds helped us to avoid the difficulty of using CPOE in our proposed system as we already had read a related paper on how to implement CPOE in easy way (Greenes, 2007; Morris et al., 2005). All the questionnaire results included in Appendix A. Based on the semi structure interview and the questionnaire, the analyst was extracting the data needed to finalize designing system, screens, database and the prescription order work flow.

4.1.4 Data Results

The results that extracted were translated into requirements. Data they analyzed and the requirements they elicited are presented in Table 3 and prescribe medication order screen sketch in Figure 17.
<table>
<thead>
<tr>
<th>Business Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Screen design requirements</strong></td>
</tr>
<tr>
<td>1. System should display drug list from prescribe medication section, and allow to choose from Physician the list and save.</td>
</tr>
<tr>
<td>2. Display of Hospital drug database in Drug Search</td>
</tr>
<tr>
<td>3. System should display History Patient profile in the pharmacy prescription page</td>
</tr>
<tr>
<td>4. System should display Patient Allergy in the pharmacy prescription page</td>
</tr>
<tr>
<td>5. System should allow any prescribed medication to be deleted before the final confirmation by physician</td>
</tr>
<tr>
<td>6. System should this prescription to the pharmacy system page</td>
</tr>
<tr>
<td><strong>Order Process requirements</strong></td>
</tr>
<tr>
<td>7. The medication selected depend on the patient problem(diagnosis)</td>
</tr>
<tr>
<td>8. Each Medication Dose/Unit to be fixed by physician based on selected drug</td>
</tr>
<tr>
<td>9. Physician should save the medication selected in medication list section</td>
</tr>
<tr>
<td>10. The doctor should decide on the alert message to add the drug or cancel with note</td>
</tr>
<tr>
<td>11. The physician can view and edit the Patient allergy</td>
</tr>
<tr>
<td>12. The physician should send the final prescribed medication tp the pharmacy department</td>
</tr>
<tr>
<td><strong>System detect requirements</strong></td>
</tr>
<tr>
<td>13. The system should check the entered medication and compare it with all medication enter in prescription , if there is drug – drug interaction</td>
</tr>
<tr>
<td>14. The system should check the entered medication and compare it with all active medication in patient history , if there is drug – drug interaction</td>
</tr>
<tr>
<td>15. The system should display Alert MSG if there is drug – drug interaction</td>
</tr>
<tr>
<td>16. The system should check the entered medication and compare it with patient allergies, if there is drug – allergy interaction</td>
</tr>
<tr>
<td>17. He system should display alert MSG if there is drug – allergy interaction</td>
</tr>
<tr>
<td>18. The system should display the ignored alert message at the top to be reviewed and double check</td>
</tr>
</tbody>
</table>
The following figure shows an early sketch of CPOE screen model evolved from the interviews where participants shared their vision when they were asked about what they would like to see when using the software.

![CPOE and Prescribe medication order screen Sketch](image)

**Figure 17: CPOE and Prescribe medication order screen Sketch**

### 4.2 System Analysis

System analysis illustrates the detailed analysis, which the system was designed upon, based on the user's requirements. We employed functionality descriptions in Use Case diagram and prescribe medication order workflow to help on system design.
4.2.1 Use case

Use cases are used in system analysis and employed in UML (Unified Modeling Language), which refers to a complete sequence of events in the system that identify system requirement from the user (Gemino & Parker, 2009). Use cases describe the main functionality of the system in a form of use case diagram in Figure 18.

![Use case diagram](image)

**Figure 18: Prescribe medication Use case diagram**

4.2.2 Use Case Description

The Main attributes for the Use case described in below table.

<table>
<thead>
<tr>
<th>Use Case Name</th>
<th>Prescribe Medication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use Case ID</td>
<td>U1</td>
</tr>
<tr>
<td>Level</td>
<td>User Goal</td>
</tr>
<tr>
<td>Primary Actor</td>
<td>Physician</td>
</tr>
<tr>
<td>Secondary Actor</td>
<td>None</td>
</tr>
<tr>
<td>Brief Description</td>
<td>This use case takes care of the Prescribe Medication order part in Doctor Portal.</td>
</tr>
<tr>
<td>Trigger</td>
<td>As part of patient examination with physician in outpatient clinic.</td>
</tr>
</tbody>
</table>
| Pre-Conditions | PC1: Physician successfully logged in to Doctor Portal  
PC2: Physician successfully search for Patient information to do treatment. |
|----------------|--------------------------------------------------------------------------|
| Flow of Events  | Step 1: The Physician logs into Doctor Portal system.  
Step 2: The Physician search for Patient in Portal using patient ID.  
Step 3: The Physician enter diagnosis and electronic order needed in the Portal.  
Step 4: Clicks on the Prescribe Medication link in Screen.  
Step 5: The physician search for medication via hospital drug database and selects the medication.  
Step 6: For the selected medicine, physician enter the following parameters (dose, route, frequency and duration) and clicking the “Prescribe Medicine” button.  
Step 7: The physician may interact with system alert if there is any error detect. He will click on “Continue” to save the drug selected in prescribed medication list.  
Step 8: The physician may repeats step 5,6,7 until all medication needed prescribed.  
Step 9: The physician looks at the Patient Allergy list to confirm any nonexistence of drug contradictions.  
Step 10: The physician saves the medication and Send.  
Step 11: On save, the pharmacy prescription further processing. |
| Alternate Flows | After step 6 (i.e. after selecting medication and save) the physician may interact with system alert if there is any error detect. He will click on “Cancel” to remove the drug selected from prescribed medication list. |
| Exception Flows | The system unable to retrieve the patient information based on patient id.  
The system unable to create prescription based on patient eligibility expiry date.  
The system may unable to retrieve the medication based on physician’s search parameter. |
| Post Conditions | POC1: The pharmacy prescription gets persisted in Doctor Portal system for the patient.  
POC2: The pharmacy prescription is transferred to Pharmacy department for further processing. |
### Extension Points

<table>
<thead>
<tr>
<th>Quality Use Case</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The system should capture the physician’s name, id, pharmacy prescription, patient id and timestamp on which the pharmacy prescription is saved for audit and quality purpose.</td>
</tr>
<tr>
<td>Business Rules</td>
<td>The list of business rules for implementing this use case was described in the Data Analysis section.</td>
</tr>
</tbody>
</table>

#### 4.2.3 Prescribe medication work flow:

The following work flow shows the processing steps required to order prescribed medication. The work flow describes how the physicians will be interacting with the system alerts by choosing one of the available actions. Click on “Continue to Prescribe medication“ to ignore this alert and add this drug to prescribed medication list or click on “Cancel Drug” to agree on message alert and delete the drug from the prescribed medication list.
Figure 19: Prescribe medication workflow
4.3 Summary

In this chapter, we have presented the gathering requirement methods for interviews and questionnaire. Then we extract the business rules requirements. Also we described the use case and prescribed medication workflow. In the following chapter, we present the system design and implementation.
Chapter 5: System design and Prototype implementation

This chapter presents the System design and the system implementation includes the database tables and the program code used.

5.1 System design

In this section we will show the system design of our project, its database and User Interface story board design.

5.1.1 Database tables Requirements

The following tables designed to store and retrieve all the data needed in e-prescription order:

1. Table to store Medical Prescription created for each patient (Prescription Master) to include Presc No., Date, Patient Details, Physician Details and Clinic Details.

2. Table to store Prescription details. This table has one to many relation with drug list table And one to many relation with the Prescription master table.

3. Table to store Pharmacy Drug list.

4. Table to store Drug Interaction rules

5. Table to store Allergy Master
5.1.2. Database Schema

A database schema is a collection of group objects such as tables that describes the relationship in the database (Cerbah, 2008).

![Database schema diagram]

Figure 20: Database schema

5.1.3 UI storyboard

User interface storyboards enable the developer to model the high-level relationships between main user interface fields, this implies us convert our hand-drawings sketch into something more clearly (Ambler, 2004). Prototype screen was designed using an Indigo Studio prototype tool as shown in Figure 21.
5.2 System Implementation

In this section we demonstrate the database table and the main code used in our prototype system.

5.2.1 Database tables

The two following tables show the partial (dummy) database used in our prototype system.
<table>
<thead>
<tr>
<th>DRUG_COD E</th>
<th>DRUG_NAME</th>
<th>UNT</th>
<th>DRUG_ FROM</th>
<th>STREN GT H</th>
<th>VO L</th>
<th>DRUG_ ITEM_ID</th>
<th>GPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMIOT2</td>
<td>amlODARONE</td>
<td>mg</td>
<td>Tablet</td>
<td>200</td>
<td>112</td>
<td></td>
<td>35-40-00-05-00-03-05</td>
</tr>
<tr>
<td>ATORT4</td>
<td>Atorvastatin Tablet</td>
<td>mg</td>
<td>Tablet</td>
<td>40</td>
<td>217</td>
<td></td>
<td>99-40-20-20-00-01-30</td>
</tr>
<tr>
<td>DIGT2</td>
<td>Digoxin</td>
<td>mcg</td>
<td>Tablet</td>
<td>250</td>
<td>902</td>
<td></td>
<td>31-20-00-10-00-03-10</td>
</tr>
<tr>
<td>CYCLC1</td>
<td>cycloSPORINE Capsule</td>
<td>mg</td>
<td>Capsule</td>
<td>100</td>
<td>705</td>
<td></td>
<td>99-40-20-20-00-01-30</td>
</tr>
<tr>
<td>CYCLC2</td>
<td>cycloSPORINE Capsule</td>
<td>mg</td>
<td>Capsule</td>
<td>25</td>
<td>706</td>
<td></td>
<td>21-30-00-50-10-21-20</td>
</tr>
<tr>
<td>METI501</td>
<td>Metronidazole</td>
<td>mg/ml</td>
<td>Vial (injectable)</td>
<td>500</td>
<td>100</td>
<td>1776</td>
<td>21-30-00-50-10-21-20</td>
</tr>
<tr>
<td>METXI5</td>
<td>Methotrexate</td>
<td>mg</td>
<td>Vial (injectable)</td>
<td>500</td>
<td>1775</td>
<td></td>
<td>16-00-00-60-10-21-05</td>
</tr>
<tr>
<td>VANCI5</td>
<td>Vancomycin</td>
<td>mg</td>
<td>Ampoule</td>
<td>500</td>
<td>2931</td>
<td></td>
<td>83-20-00-30-20-03-05</td>
</tr>
<tr>
<td>WART5</td>
<td>Warfarin Sodium</td>
<td>mg</td>
<td>Tablet</td>
<td>5</td>
<td>2971</td>
<td></td>
<td>01-99-00-02-16-01-20</td>
</tr>
<tr>
<td>XXXX1</td>
<td>Amoxicillin &amp; Ambroxol Cap 500-30 MG</td>
<td>mg</td>
<td>Capsule</td>
<td></td>
<td></td>
<td></td>
<td>39-40-00-10-10-03-30</td>
</tr>
<tr>
<td>XXXX2</td>
<td>Atorvastatin Calcium Oral Tablet 40 MG</td>
<td>mg</td>
<td>Tablet</td>
<td></td>
<td></td>
<td></td>
<td>17-10-00-20-61-E6-20</td>
</tr>
<tr>
<td>XXXX3</td>
<td>Influenza A (H1N1) Monoval Vac Split PF Susp Pref Syr 0.5 ML</td>
<td>mg</td>
<td>Tablet</td>
<td></td>
<td></td>
<td></td>
<td>39-40-00-10-10-03-30</td>
</tr>
<tr>
<td>XXXX4</td>
<td>Atorvastatin Calcium Oral Tablet 40 MG</td>
<td>mg</td>
<td>Tablet</td>
<td></td>
<td></td>
<td></td>
<td>64-20-00-10-00-01-15</td>
</tr>
<tr>
<td>XXXX5</td>
<td>Acetaminophen Cap 500 MG</td>
<td>mg</td>
<td>Capsule</td>
<td></td>
<td></td>
<td></td>
<td>17-10-00-20-61-E6-20</td>
</tr>
<tr>
<td>XXXX6</td>
<td>Influenza A (H1N1) Monoval Vac Split PF Susp Pref Syr 0.5 ML</td>
<td>mg</td>
<td>Capsule</td>
<td></td>
<td></td>
<td></td>
<td>39-40-00-10-10-03-30</td>
</tr>
<tr>
<td>XXXX7</td>
<td>Atorvastatin Calcium Oral Tablet 40 MG</td>
<td>mg</td>
<td>Tablet</td>
<td></td>
<td></td>
<td></td>
<td>64-20-00-10-00-01-15</td>
</tr>
<tr>
<td>XXXX8</td>
<td>Acetaminophen Cap 500 MG</td>
<td>mg</td>
<td>Capsule</td>
<td></td>
<td></td>
<td></td>
<td>64-20-00-10-00-01-15</td>
</tr>
</tbody>
</table>
Generic Product Identifier (GPI) column is identifier (the Drug name and related details) to be used in the vendor database file as input for drug – interaction and drug allergy detect function code.

There are three Allergy types as common. Allergen Class, Ingredient and allergy on specific drug (GPI) as Drug name, Unit, Drug form and strength:

1. **Allergen Class (PAR):**

   Drugs are grouped into classes based on similarities in chemical/biologic source. Such as Drug “A” prescribed for a patient with a stored Drug” B” (the same class of Drug A) allergy.

2. **Ingredient (KDC-5):**

   The prescribed drug contains the ingredient to which the patient is Allergic. Such as Drug “A” (with ingredient “C”) prescribed for a patient with a stored ingredient “C” allergy.

3. **Generic Product Identifier (GPI):**

   Allergy against specific drug (GPI) which the patient is Allergic. Such as Drug “A” (with drug format details “C”) prescribed for a patient with a stored GPI “C” allergy.

**Table 6: Allergy table**

<table>
<thead>
<tr>
<th>ALLERGY_CODE</th>
<th>ALLERGY_DESCRIPTION</th>
<th>ALLERGY_TYPE</th>
<th>ALLERGY_FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Penicillins</td>
<td>Allergen Class (Common)</td>
<td>PAR</td>
</tr>
<tr>
<td>76</td>
<td>Statins</td>
<td>Allergen Class (Common)</td>
<td>PAR</td>
</tr>
<tr>
<td>12</td>
<td>Eggs or Egg-derived</td>
<td>Allergen Class</td>
<td>PAR</td>
</tr>
<tr>
<td></td>
<td>Products</td>
<td>(Common)</td>
<td>Allergen Class</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>57</td>
<td>NSAIDs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8562</td>
<td>Atorvastatin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Acetaminophen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>985</td>
<td>Penicillin V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24101</td>
<td>Influenza Vaccine Live</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Atorvastatin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Acetaminophen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SQL server used to build the following database tables, three tables are implemented to be used in the two main detect functions code in addition of vendor database files we installed.

![Table](image)

**Figure 22: PRESCRIPTION_MASTER Table**
### Figure 23: PRESCRIPTIONDETAIL Table

<table>
<thead>
<tr>
<th>PRESCR NO</th>
<th>DRUG_CODE</th>
<th>DOSE</th>
<th>ROUTE</th>
<th>FREQUENCY</th>
<th>DURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>CARBM1</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>24</td>
<td>CALCIB</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>41</td>
<td>ACEI2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>61</td>
<td>ACETI2</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
</tr>
<tr>
<td>81</td>
<td>ADRE110</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>83</td>
<td>AMOC5</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>83</td>
<td>ACTI15</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>88</td>
<td>DIGT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>87</td>
<td>AMIOT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>88</td>
<td>AMIOT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>88</td>
<td>METI501</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>90</td>
<td>AMIOT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>90</td>
<td>DIGT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>108</td>
<td>AMIOT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>108</td>
<td>DIGT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>111</td>
<td>AMIOT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>111</td>
<td>DIGT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>113</td>
<td>AMIOT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>113</td>
<td>DIGT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>116</td>
<td>AMIOT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>116</td>
<td>DIGT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>116</td>
<td>VANCO5</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>127</td>
<td>AMIOT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
<tr>
<td>142</td>
<td>DIGT2</td>
<td>1TAB</td>
<td>Mouth</td>
<td>BID</td>
<td>2 weeks</td>
</tr>
</tbody>
</table>

### Figure 24: ALLERGYMASTER Table

<table>
<thead>
<tr>
<th>ALLERGY_CODE</th>
<th>ALLERGY_DESCRIPTION</th>
<th>ALLERGY_TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Penicillins</td>
<td>Allergen Class (Common)</td>
</tr>
<tr>
<td>76</td>
<td>Stelins</td>
<td>Allergen Class (Common)</td>
</tr>
<tr>
<td>12</td>
<td>Eggs or Egg-derived Products</td>
<td>Allergen Class (Common)</td>
</tr>
<tr>
<td>57</td>
<td>NSADs</td>
<td>Allergen Class (Common)</td>
</tr>
<tr>
<td>05562</td>
<td>Atorvastatin</td>
<td>Ingradiant (Common)</td>
</tr>
<tr>
<td>00005</td>
<td>Acetaminophen</td>
<td>Ingradiant (Common)</td>
</tr>
<tr>
<td>00365</td>
<td>Penicillin V</td>
<td>Ingradiant (Common)</td>
</tr>
<tr>
<td>24101</td>
<td>Influenza Vaccine Live</td>
<td>Ingradiant (Common)</td>
</tr>
<tr>
<td>39</td>
<td>Atorvastatin</td>
<td>GPI</td>
</tr>
<tr>
<td>64</td>
<td>Acetaminophen</td>
<td>GPI</td>
</tr>
</tbody>
</table>
5.2.2 Prescribe medication order screen code

We designed and developed the order screen by Microsoft .Net and created the main functions for the prescription order process. The CDSS vendor provides us the API and database files for detecting the error and alert message.

The main two functions in our system are detecting Drug – Drug Interaction and Detect Drug – Allergy interaction.
5.2.2.1 Drug –Drug Interaction detect

This function compares the prescribed drugs list against new drug being prescribed. The function code was developed as below:

```csharp
public void SSCCE_51_DoDIInteractionScreen_ForGPI(string GPI)
{
    // Setting up the Patient Profile
    PatientProfile thePatient = new PatientProfile(filter);
    thePatient.BirthDate = new DateTime(1980, 1, 1);
    thePatient.Gender = MediSpan.Concepts.Gender.Male(filter);
    DataSet DS_GPI = WS1.Fetch_GPI_FULL(IblTemp.Text);
    DataTable DT_GPI = DS_GPI.Tables[0];
    if (DS_GPI.Tables[0].Rows.Count > 0)
    {
        string inputDrug1;
        for (int i = 0; i < DT_GPI.Rows.Count; i++)
        {
            inputDrug1 = DT_GPI.Rows[i]["GPI"].ToString();
            MediSpan.Concepts.TherapeuticClassification.GenericProduct.SelectByGPI(filter, inputDrug1);
            PatientDrug oldDrug = new PatientDrug(drug);
            oldDrug.Screen = false;
            thePatient.PatientDrugs.Add(oldDrug);
        }
        MediSpan.Concepts.TherapeuticClassification.GenericProduct.SelectByGPI(filter, GPI);
        PatientDrug newDrug = new PatientDrug(drugNew);
        newDrug.Screen = true;
        thePatient.PatientDrugs.Add(newDrug);
    }
    else
    {
        MediSpan.Concepts.TherapeuticClassification.GenericProduct.SelectByGPI(filter, GPI);
        PatientDrug newDrug = new PatientDrug(drugNew);
        newDrug.Screen = true;
        thePatient.PatientDrugs.Add(newDrug);
    }
    MediSpan.Interactions.FilterManager.MinimumDocumentationLevelForModerateSeverityLevel(filter,
    MediSpan.Interactions.DocumentationLevel.Doubtful(filter));
    MediSpan.Interactions.FilterManager.MinimumManagementLevel(filter,
    // Interactions for the Patient Profile
    MediSpan.Interactions.Result result = DrugDrugResult.ForPatientProfile(filter,
    thePatient);
}
MediSpan.Foundation.Collections.List<Interaction> interactions = result.Interactions;
GeneralMemoryTable.Columns.Add(new DataColumn("ALERT_MSG", typeof(string)));
GeneralMemoryTable.Columns.Add(new DataColumn("SERVERITY LEVEL", typeof(string)));
GeneralMemoryTable.Columns.Add(new DataColumn("MESSAGES", typeof(string)));
int InteractionCount = result.Interactions.Count;
if (InteractionCount > 0)
{
    int k = 0;
    foreach (Interaction interaction in interactions)
    {
        k++;
        dr = GeneralMemoryTable.NewRow();
        dr["ALERT_MSG"] = k.ToString();
        dr["MESSAGES"] = interaction.Message;
        dr["SERVERITY LEVEL"] = interaction.Definition.ServerityLevel.Name;

        GeneralMemoryTable.Rows.Add(dr);
    }

    Session["Sorting"] = GeneralMemoryTable;
    GridView1.DataSource = GeneralMemoryTable;
    GridView1.DataBind();
    GridViewmodal.DataSource = GeneralMemoryTable;
    GridViewmodal.DataBind();
}
if (interactions.Count != 0)
{
    btnContPresDrug.Text = "Continue Prescribe Drug";
    commentarea.Visible = true;
    Page.ClientScript.RegisterStartupScript(GetType(), "MyKey", "selectsabir();", true);
}
else
{
    GridView1.Visible = false;
    this.SavePrescription();
    Panel3.Visible = true;
    this.clear();
}
5.2.2.2 Drug – Allergy detect

This function compares the allergies in the patient profile against drug being prescribed. The function code was developed as below:

```java
public void newmethod(ArrayList allergy_code, string GPI)
{
    PatientProfile patient = new PatientProfile();
        MediSpan.Concepts.TherapeuticClassification.GenericProduct.SelectByGPI(filter, GPI);
    int arraycount = allergy_code.Count;
    for (int i = 0; i <= arraycount - 1; i++)
    {
        string val = allergy_code[i].ToString();
        string MedispanAllergyFormat = Before(val, ",");
        string AllergyCode = After(val, ",");
        if (MedispanAllergyFormat == "PAI")
        {
            MediSpan.AllergicReactions.AllergenClass par =
                MediSpan.AllergicReactions.AllergenClass.SelectByMediSpanId(filter, AllergyCode);
            patient.PatientAllergies.Add(new MediSpan.Screening.PatientAllergy(par));
        }
        else if (MedispanAllergyFormat == "GPI")
        {
                MediSpan.Concepts.TherapeuticClassification.GenericProduct.SelectByGPI(filter, AllergyCode);
        }
        else if (MedispanAllergyFormat == "KDC-5")
        {
            MediSpan.Concepts.Ingredients.ScreenableIngredient kdc =
                MediSpan.Concepts.Ingredients.ScreenableIngredient.SelectByMediSpanId(filter, AllergyCode);
            patient.PatientAllergies.Add(new MediSpan.Screening.PatientAllergy(kdc));
        }
    }
    MediSpan.AllergicReactions.Result result =
        MediSpan.AllergicReactions.Result.ForPatientProfile(filter, patient);
    string ScreeningResult = result.PassesScreening.ToString(); string ScreeningMessage = result.Message;
    Lblblank.Text = "";
    if (ScreeningResult == "True")
    {
        // write code to check drug to drug interaction
        this.SSCCE_51_DoIIInteractionScreen_ForGPI(GPI);
    }
    else
    {
        Lblblank.Text = ScreeningMessage;
        btnContinuePres.Text = "Continue with Allergy?";
        commentsArea.Visible = true;
        Page.ClientScript.RegisterStartupScript(GetType(), "MyKey", "selectsabir();", true);
    }
}
```
5.2.3 Prescribe medication screens

The main screen of Prescription page contains the following sections, as a Figure 25:

- Doctor and patient details.
- Medication History: the history of patient’s drug list.
- Prescription: to select the “Drug Name” and related details, then click on “Prescribe medicine”.
- Patient Allergies: list of patient’s allergies.

![Figure 25: Main screen for prescribing medication order](image)
When the physicians prescribes the medicine, if there is a drug-drug interaction or drug–allergy interaction, the system generates a pop up alert message. The alert message has three related pieces of information: Alert No, Severity Level (Major – Moderate – Low) and the body message that describes the interaction details. The physician should decide to click on “Continue prescribe Drug” or “Cancel Drug” and write remarks in the comment box if he decides to continue to prescribe the drug. The alert message is shown in Figure 26.

![Figure 26: Pop up Alert Message for drug interaction](image)

Even if he decides to continue to prescribe certain drugs, the alert message will be appear at the top of the page up to be reviewed all the time and before to send it to the pharmacy. The physician can delete it later as a Figure 27.
5.3 Summary

In the chapter, we have showed the system design with database tables requirements, database schema and user interface. Also the developed code for the main functions and the final system screens with description. In the following chapter, we present the evaluation done and the results.
Chapter 6: Evaluation & Discussion

In this chapter, testing, results and discussion are presented in order to examine and discuss the effectiveness and powerfulness of the system.

6.1 Evaluation

After the prototype was built, two evaluations are done for the system, first by testing experts to remove any bugs, the other by end users (physician) by applying User Acceptance Testing (UAT) to ensure that the system is meeting, this should read the requirements ‘s need.

6.1.1 Evaluation by testing expert

The tester did testing on the system that was developed to discover faults or defects in the system and where its behavior is incorrect or does not meet the specifications before they hand it over to end users to start User Acceptance Testing. The expert working under the development department in IT. He has experience in the same field for more than 7 years in a hospital and he was aware about the research objectives. He has worked as a tester and be a familiar with the similarity project like doctor portal. A successful test done for all the following functions:

1. Test the login function using correct and incorrect logins to check that validity of users.
2. Test patient search facility using different patient ID numbers to check that the search results is actually finding correct patient’s detail.
3. Test the system responds when click on “Prescribe medication order” page
4. Test the drug search facility using different selections on medicine to check that the search mechanism is actually finding selected one.
5. Test the mechanism to request new drug to add it in prescription list or to delete from the list.
6. Test the alert message response indicating that there is drug-drug interaction or drug-allergy interaction.
7. Test the user actions on the alert message.

Test the system presentation facility to check that information about the patient and all medicine detail lists are displayed properly.

6.1.2 Evaluation by end users (Physicians)

After the defect testing is done, the UAT is a process where the end users evaluating a new system to make sure it meets their business requirements needs (Davis & Venkatesh, 2004). The goal of the user acceptance testing was to determine the degree of user acceptance for two selected modules of CDSS. The testing was done using demonstration sessions in which physicians participated in scenario testing. Their satisfaction on system usability was elicited using System User Scale (SUS) testing. SUS is questioner test developed by Brooke, its asked user to fill 10 questions on Likert style metric rating on a five point scale of “Strongly Disagree” to “Strongly Agree” (Brooke,1996) (Tullis and Jacqueline,2004). The goal of SUS is to measure the user satisfaction of the system and elicit their feedback.

6.1.2.1 Participants

In order to start doing UAT, we had confirmed the participant (physicians) names in testing. We have chosen the physician role because it is their own practice and they can view the system from a business side rather than the IT staff who will view the system from a technical side.
Six male physicians between 35-45 years old and with general specialty have been a participant. Those physicians are selected from the medical team of the “Doctor Portal” project to be more familiar on the goal of this research.

6.1.2.2 Setting

The test environment was established by the IT department at the training room. Technical and Physical requirements includes desktops, chairs, the PCs, network and the main demo screen.

6.1.2.3 Material

The UAT document was prepared by the analyst depend on the business requirements to present different test cases with style scenario testing for the two types of CDSS. IEEE Standard 610 (1990) defines the test case as the tests to be performed by end users with any specific data or conditions and the expected results in order to evaluate business requirements of the system. A scenario is a story that describes a hypothetical situation. In testing, users check how the program interacts with this hypothetical situation (Cem, 2003). The most important objectives behind running the test cases are found defects and Improve software quality (Cem, 2003).

For test data the CDSS provider selected medicines and an allergy list to be tested, the common medicine name causes the two types of error (drug – drug interaction and drug allergy. SUS questionnaire form placed in the last page of UAT document, appendix A shows the SUS form.
6.1.2.4 Procedure

Two evaluation sessions were conducted with three physicians for each session. The session placed in main training room in IT department and lasted four hours starting form 10 am excluding a one hour break from 12-1 pm for two days. For the First 45 minutes the project manager (PM) gave a demonstration of how this prototype system works with instructions .PM started with CPOE main screen after login the system and enter testing patient ID to be used as data test for all cases then click on prescribe medication request page and focus on CDSS alert interactions .At the end of demo PM distributed the UAT document to the tester (physician) then gave instruction of how using it and how to fill the documents.

The tester run the system using their user name and password to access and followed the test case steps in UAT. The tester then records the result for each test case as detailed in “Test cases” section, the result will be either ‘Pass’ or ‘Fail’. If the test was failed, the tester recorded a “defect log” form, reported it to the IT developer to fix it and tested it again when resolved. The defect log includes the date, test case number and the actual result. The tester fills the SUS form to get their feedback. At the end of the evaluation session, the PM collects the documents to analyze the results.

6.1.2.5 Test cases

The test cases done by the tester are in the details below, the tester reads the steps, then fill the ‘Test Date’, ‘Actual result’ and ‘Defect Log No.’ if the result was Fail.
Test No.1
Test Date:
Summary: To test drug–drug interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.

- Medicine1: Amiodarone Tabs 200mg  AND Medicine2: Digoxin Tabs 0.25mg

Pre-Condition(s):
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

Post-Condition(s):
- n.a

<table>
<thead>
<tr>
<th>Test steps</th>
<th>Expected result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Invoke the prototype by enter below URL in the browser</td>
<td>1. Doctor should be able to access E-prescription prototype</td>
</tr>
<tr>
<td><a href="http://xxxxxxx/E-prescription/">http://xxxxxxx/E-prescription/</a></td>
<td></td>
</tr>
<tr>
<td>2. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>2. Drug name is selected in the drop-down list .Fig.1-Test No.1</td>
</tr>
<tr>
<td>3. Click on ‘Prescribe Medicine’ button below</td>
<td>3. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’ .Fig.2-Test No.1</td>
</tr>
<tr>
<td>4. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>4. Drug name is selected in the drop-down list .Fig.3-Test No.1</td>
</tr>
<tr>
<td>5. Click on ‘Prescribe Medicine’ button below</td>
<td>5. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.4-Test No.1</td>
</tr>
<tr>
<td>6. Click on ‘Continue to Prescribe Drug’ button</td>
<td>6. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’ .Fig.5-Test No.1</td>
</tr>
</tbody>
</table>

Expected Results:
Test case screen 1: (Fig.1-Test No.1) Prescribing Medicine1

Test case screen 2: (Fig.2-Test No.1) Medicine1 prescribed
Test case screen 3: (Fig.3-Test No.1) Prescribing Medicine2

Test case screen 4: (Fig.4-Test No.1) Pop up Alert Message

Test case screen 5: (Fig.5-Test No.1) Medicine2 added when “Continue Prescribe Drug” clicked
Test No.2
Test Date:
Summary: To test drug – drug interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.
  - Medicine1: Amiodarone Tabs 200mg AND Medicine2: Digoxin Tabs 0.25mg
Pre-Condition(s):
  - User should have access to the system
  - User should click on “Prescribe Medication” request on the main CPOE screen
Post-Condition(s):
  - n.a

<table>
<thead>
<tr>
<th>Test steps</th>
<th>Expected result</th>
</tr>
</thead>
</table>
| 1. Invoke the prototype by enter below URL in the browser  
   http://xxxxxxx/E-prescription/ | 1. Doctor should be able to access E-prescription prototype |
| 2. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 2. Drug name is selected in the drop-down list. Fig.1-Test No.1 |
| 3. Click on ‘Prescribe Medicine’ button below | 3. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. Fig.2-Test No.1 |
| 4. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 4. Drug name is selected in the drop-down list. Fig.3-Test No.1 |
| 5. Click on ‘Prescribe Medicine’ button below | 5. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.4-Test No.1 |
| 6. Click on ‘Cancel Drug’ button | 6. Selected drug name should not be selected in prescription. Fig.6-Test No.2 |

Expected Results:
Test No.3
Test Date:
Summary: To test drug–drug interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.
- **Medicine1**: Vancomycin HCl For Inj 500 MG **AND** **Medicine2**: Methotrexate Sodium For Inj 100 MG

Pre-Condition(s):
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

Post-Condition(s):
- n.a

<table>
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<tr>
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</tr>
</thead>
</table>
| 1. Invoke the prototype by enter below URL in the browser  
http://xxxxxxx/E-prescription/ | 1. Doctor should be able to access E-prescription prototype |
| 2. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 2. Drug name is selected in the drop-down list. |
| 3. Click on ‘Prescribe Medicine’ button below | 3. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. Fig.1-Test No.3 |
| 4. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 4. Drug name is selected in the drop-down list. Fig.2-Test No.3 |
5. Click on ‘Prescribe Medicine’ button below

6. Click on ‘Continue to Prescribe Drug’ button

5. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.3-Test No.3

6. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’.

Expected Result:

Test case screen 7: (Fig.1-TestNo.3)Medicine1 Prescribed

Test case screen 8: (Fig.2-TestNo.3)Prescribing Medicine 2
Test No.4  
Test Date: 
Summary: To test drug –drug interaction feature  
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.  
- Medicine1: Vancomycin HCl For Inj 500 MG AND Medicine2: Methotrexate Sodium For Inj 100 MG  
Pre-Condition(s):  
- User should have access to the system  
- User should click on “Prescribe Medication” request on the main CPOE screen  
Post-Condition(s):  
- n.a  

<table>
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<tr>
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</table>
| 1. Invoke the prototype by enter below URL in the browser  
http://xxxxxxx/E-prescription/  
2. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration  
3. Click on ‘Prescribe Medicine’ button below  
4. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 1. Doctor should be able to access E-prescription prototype  
2. Drug name is selected in the drop-down list  
3. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. Fig .1-Test No.3  
4. Drug name is selected in the drop-down list. Fig.2-Test No.3 |
5. Click on ‘Prescribe Medicine’ button below

6. Click on ‘Cancel Drug’ button

5. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.3-Test No.3

6. Selected drug name should not be selected in prescription. Fig.4-Test No.4

Expected Results:

Test case screen 10: (Fig.4-Test No.4) Medicine2 removed when “Cancel Drug” clicked

Test No.5
Test Date:
Summary: To test drug –drug interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.

- **Medicine1**: Atorvastatin Calcium Tab 40 MG AND **Medicine2**: Cyclosporine Cap 50 MG

Pre-Condition(s):
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

Post-Condition(s):
- n.a

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<td>1. Doctor should be able to access E-prescription prototype</td>
</tr>
<tr>
<td><a href="http://xxxxxxx/E-prescription/">http://xxxxxxx/E-prescription/</a></td>
<td></td>
</tr>
<tr>
<td>2. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>2. Drug name is selected in the drop-down list. Fig.1-Test No.5</td>
</tr>
<tr>
<td>3. Click on ‘Prescribe Medicine’ button below</td>
<td>3. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’.</td>
</tr>
</tbody>
</table>
4. Select the relevant ‘Drug Name2’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration

5. Click on ‘Prescribe Medicine’ button below

6. Click on ‘Continue to Prescribe Drug’ button

4. Drug name is selected in the drop-down list. Fig.2-Test No.5

5. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.3-Test No.5

6. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. Fig.4-Test No.5

Expected Results:

Test case screen 11: (Fig.1-Test No.5) Prescribing Medicine1

Test case screen 12: (Fig.2-Test No.5) Prescribing Medicine2
Test case screen 13: (Fig.3-Test No.5) Pop up Alert Message

Test case screen 14: (Fig.4-Test No.5) Medicine2 added when “Continue Prescribe Drug” clicked
Test No.6
Test Date:
Summary: To test drug–drug interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.

Medicine1: Atorvastatin Calcium Tab 40 MG  AND  Medicine2: Cyclosporine Cap 50 MG

Pre-Condition(s):
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

Post-Condition(s):
- n.a

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<tr>
<td>1. Invoke the prototype by enter below URL in the browser</td>
<td>1. Doctor should be able to access E-prescription prototype</td>
</tr>
<tr>
<td><a href="http://xxxxxxx/E-prescription/">http://xxxxxxx/E-prescription/</a></td>
<td>2. Drug name is selected in the drop-down list Fig.1-Test No.5</td>
</tr>
<tr>
<td>2. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>3. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. Fig.2-Test No.5</td>
</tr>
<tr>
<td>3. Click on ‘Prescribe Medicine’ button below</td>
<td>4. Drug name is selected in the drop-down list Fig.2-Test No.5</td>
</tr>
<tr>
<td>4. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>5. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.3-Test No.5</td>
</tr>
<tr>
<td>5. Click on ‘Prescribe Medicine’ button below</td>
<td>6. Selected drug name should not be selected in prescription. Fig.5-Test No.6</td>
</tr>
<tr>
<td>6. Click on ‘Cancel Drug’ button</td>
<td></td>
</tr>
</tbody>
</table>

Expected Results:

Test case screen 15: (Fig.5-Test No.6) Medicine2 removed when “Cancel Drug” clicked
Test No.7

Test Date:

Summary: To test drug–drug interaction feature

Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.

- Medicine1: Cyclosporine Cap 50 MG
  - Medicine2: Warfarin Sodium Tab 2 MG
  - Medicine3: Vancomycin HCl For Inj 500 MG
  - Medicine4: MetroNIDAZOLE Oral Tablet 500 MG

Pre-Condition(s):
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

Post-Condition(s):
- n.a

<table>
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<tr>
<th>Test steps</th>
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</tr>
</thead>
</table>
| 1. Invoke the prototype by enter below URL in the browser
  http://xxxxxxx/E-prescription/ | 1. Doctor should be able to access E-prescription prototype |
| 2. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 2. Drug name is selected in the drop-down list . |
| 3. Click on ‘Prescribe Medicine’ button below | 3. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. |
| 4. Select the relevant ‘Drug Name3 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 4. Drug name is selected in the drop-down list . |
| 5. Click on ‘Prescribe Medicine’ button below | 5. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. |
| 6. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 6. Drug name is selected in the drop-down list . |
| 7. Click on ‘Prescribe Medicine’ button below | Fig.1-Test No.7 |
| 8. Click on ‘Continue to Prescribe Drug’ button | 7. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.2-Test No.7 |
| 9. Select the relevant ‘Drug Name4 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration | 8. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. |
10. Click on ‘Prescribe Medicine’ button below

11. Click on ‘Continue to Prescribe Drug’ button

9. Drug name is selected in the drop-down list.

   Fig.3-Test No.7

10. If there’s a drug interaction, then system should pop-up an alert message for drug interaction.

   Fig.4-Test No.7

11. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’.

Expected Results:

Test case screen 16: (Fig.1-Test No.7) Prescribing Medicine

Test case screen 17: (Fig.2-Test No.7) Pop up Alert Message
Test case screen 18: (Fig.3-Test No.7) Prescribing Medicine

Test case screen 19: (Fig.4-Test No.7) Many Alert Message
Test No.8
Test Date:
Summary: To test drug–drug interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.
- Medicine1: Cyclosporine Cap 50 MG AND Medicine2: Warfarin Sodium Tab 2 MG
- Medicine3: Vancomycin HCl For Inj 500 MG AND Medicine4: MetroNIDAZOLE Oral Tablet 500 MG
- Medicine2: Warfarin Sodium Tab 2 MG AND Medicine4: MetroNIDAZOLE Oral Tablet 500 MG
- Medicine1: Cyclosporine Cap 50 MG AND Medicine4: MetroNIDAZOLE Oral Tablet 500 MG

Pre-Condition(s):
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

Post-Condition(s):
- n.a

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</thead>
<tbody>
<tr>
<td>1. Invoke the prototype by enter below URL in the browser</td>
<td>1. Doctor should be able to access E-presentation prototype</td>
</tr>
<tr>
<td><a href="http://xxxxxxx/E-prescription/">http://xxxxxxx/E-prescription/</a></td>
<td>2. Drug name is selected in the drop-down list</td>
</tr>
<tr>
<td>2. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>3. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’ .</td>
</tr>
<tr>
<td>3. Click on ‘Prescribe Medicine’ button below</td>
<td>4. Drug name is selected in the drop-down list</td>
</tr>
<tr>
<td>4. Select the relevant ‘Drug Name3 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>5. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’ .</td>
</tr>
<tr>
<td>5. Click on ‘Prescribe Medicine’ button below</td>
<td>6. Drug name is selected in the drop-down list</td>
</tr>
<tr>
<td>6. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>7. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.2-Test No.7</td>
</tr>
<tr>
<td>7. Click on ‘Prescribe Medicine’ button below</td>
<td>8. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE,</td>
</tr>
<tr>
<td>8. Click on ‘Continue to Prescribe Drug’ button</td>
<td></td>
</tr>
</tbody>
</table>
10. Click on ‘Prescribe Medicine’ button below FREQUENCY, DURATION’.

11. Click on ‘Cancel Drug’ button

9. Drug name is selected in the drop-down list. Fig.3-Test No.7

10. If there’s a drug interaction, then system should pop-up an alert message for drug interaction. Fig.4-Test No.7

11. Selected drug name should not be selected in prescription. Fig.5-Test No.8

Expected Results:

Test case screen 20: (Fig.5-Test No.8) Medicine4 removed when “Cancel Drug” clicked
Test No.9
Test Date:
Summary: To test drug—allergy interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.

- **Medicine1**: Acetaminophen Cap 500 MG
- **Allergy1**: Penicillin (PAR) AND **Medicine2**: Amoxicillin & Ambroxol Cap 500-30 MG
- **Allergy2**: Eggs or Egg-derived Products (PAR) AND **Medicine3**: Influenza A (H1N1) Monoval Vac Split PF Susp Pref Syr 0.5 ML

**Pre-Condition(s):**
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

**Post-Condition(s):**
- n.a

<table>
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<tbody>
<tr>
<td>1. Invoke the prototype by enter below URL in the browser  &lt;br&gt; <a href="http://xxxxxxx/E-prescription/">http://xxxxxxx/E-prescription/</a></td>
<td>1. Doctor should be able to access E-prescription prototype</td>
</tr>
<tr>
<td>2. Select ‘Allergy1 ’ and ‘Allergy2’ from ‘Patient Allergies’ Section.</td>
<td>2. Allergies are selected in the ‘Patient Allergies’ Section. Fig.1-Test No.9</td>
</tr>
<tr>
<td>3. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>3. Drug name is selected in the drop-down list . Fig.2-Test No.9</td>
</tr>
<tr>
<td>4. Click on ‘Prescribe Medicine’ button below</td>
<td>4. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. Fig.3-Test No.9</td>
</tr>
<tr>
<td>5. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>5. Drug name is selected in the drop-down list . Fig.3-Test No.9</td>
</tr>
<tr>
<td>6. Click on ‘Prescribe Medicine’ button below</td>
<td>6. If there’s an allergy interaction, then system should pop-up an alert message for allergy interaction. Fig.4-Test No.9</td>
</tr>
<tr>
<td>7. Click on ‘Continue to Prescribe Drug’ button</td>
<td>7. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. Fig.5-Test No.9</td>
</tr>
<tr>
<td>8. Select the relevant ‘Drug Name3 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>8. Drug name is selected in the drop-down list . Fig.6-Test No.9</td>
</tr>
<tr>
<td>9. Click on ‘Prescribe Medicine’ button below</td>
<td>9. If there’s an allergy interaction, then system should pop-up an alert message for allergy interaction. Fig.7-Test No.9</td>
</tr>
<tr>
<td>10. Click on ‘Cancel Drug’ button</td>
<td>10. Selected drug name should not be selected in prescription. Fig.8-Test No.9</td>
</tr>
</tbody>
</table>
Expected Results:

Test case screen 21: (Fig.1-Test No.9) Selecting Allergy1 and Allergy2

Test case screen 22: (Fig.2-Test No.9) Medicine1 prescribed
Test case screen 23: (Fig.3-Test No.9) Prescribing Medicine2

Test case screen 24: (Fig.4-Test No.9) Pop up Alert Message
Test case screen 25: (Fig.5-Test No.9) Medicine2 added when “Continue Prescribe Drug” clicked

Test case screen 26: (Fig.6-Test No.9) Prescribing Medicine3

Test case screen 27: (Fig.7-Test No.9) Pop up Alert Message
Test No.10
Test Date:
Summary: To test drug–allergy interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.

- **Allergy1**: Atorvastatin (KDC-5) **AND Medicine1**: Atorvastatin Calcium Oral Tablet 40 MG
- **Allergy2**: Statins (PAR) **AND Medicine1**: Atorvastatin Calcium Oral Tablet 40 MG
- **Medicine2**: Amiodarone Tabs 200mg
- **Allergy3**: Influenza Vaccine Live (KDC-5) **AND Medicine3**: Influenza A (H1N1) Monoval Vac Split PF Susp Pref Syr 0.5 ML

**Pre-Condition(s):**
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

**Post-Condition(s):**
- n.a

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<tr>
<td>1. Invoke the prototype by enter below URL in the browser</td>
<td>1. Doctor should be able to access E-prescription prototype</td>
</tr>
<tr>
<td><a href="http://xxxxxxx/E-prescription/">http://xxxxxxx/E-prescription/</a></td>
<td>2. Allergies are selected in the ‘Patient Allergies’ Section. Fig.1-Test No.10</td>
</tr>
<tr>
<td>2. Select ‘Allergy1 ’, ‘Allergy2’ and ‘Allergy3’ from ‘Patient Allergies’ Section.</td>
<td>3. Drug name is selected in the drop-down list .Fig.2-Test No.10</td>
</tr>
<tr>
<td>3. Select the relevant ‘Drug Name1 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>4. If there’s an allergy interaction, then system should pop-up an alert message for allergy interaction. Fig.3-Test No.10</td>
</tr>
<tr>
<td>4. Click on ‘Prescribe Medicine’ button below</td>
<td>5. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’ . Fig .4-Test No.10</td>
</tr>
<tr>
<td>5. Click on ‘Continue to Prescribe Drug’ button</td>
<td>6. Drug name is selected in the drop-down list .</td>
</tr>
<tr>
<td>6. Select the relevant ‘Drug Name2 ’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td></td>
</tr>
</tbody>
</table>
7. Click on ‘Prescribe Medicine’ button below  
8. Select the relevant ‘Drug Name3’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration
9. Click on ‘Prescribe Medicine’ button below
10. Click on ‘Cancel Drug’ button

7. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’. Fig .5-Test No.10
8. Drug name is selected in the drop-down list. Fig .6-Test No.10
9. If there’s an allergy interaction, then system should pop-up an alert message for allergy interaction. Fig.7-Test No.10
10. Selected drug name should not be selected in prescription. Fig.8-Test No.10

Expected Results:

Test case screen 29: (Fig.1-Test No.10) Selecting Allergy1, Allergy2 and Allergy3

Test case screen 30: (Fig.2-Test No.10) Prescribing Medicine1
Test case screen 31: (Fig.3-Test No.10) Pop up Alert Message

Test case screen 32: (Fig.4-Test No.10) Medicine1 added when “Continue Prescribe Drug” clicked

Test case screen 33: (Fig.5-Test No.10) Medicine2 Prescribed
Test case screen 34: (Fig.6-Test No.10) Prescribing Medicine 3

Test case screen 35: (Fig.7-Test No.10) Pop up Alert Message

Test case screen 36: (Fig.8-Test No.10) Medicine 3 removed when “Cancel Drug” clicked
**Test No.11**

**Test Date:**

**Summary:** To test drug–allergy interaction feature

**Description:** When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.

- **Allergy1:** Acetaminophen(KDC-5) **AND Medicine1:** Acetaminophen Cap 500 MG
- **Allergy2:** Atorvastatin (GPI) **AND Medicine2:** Atorvastatin Calcium Oral Tablet 40 MG

**Pre-Condition(s):**

- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

**Post-Condition(s):**

- n.a

<table>
<thead>
<tr>
<th>Test steps</th>
<th>Expected result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Invoke the prototype by enter below URL in the browser</td>
<td>1. Doctor should be able to access E-prescription prototype</td>
</tr>
<tr>
<td><a href="http://xxxxxxx/E-prescription/">http://xxxxxxx/E-prescription/</a></td>
<td></td>
</tr>
<tr>
<td>2. Select ‘Allergy1’ and ‘Allergy2’ from ‘Patient Allergies’ Section.</td>
<td>2. Allergies are selected in the ‘Patient Allergies’ Section. Fig.1-Test No.11</td>
</tr>
<tr>
<td>3. Select the relevant ‘Drug Name1’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td>3. Drug name is selected in the drop-down list. Fig.2-Test No.11</td>
</tr>
<tr>
<td>4. Click on ‘Prescribe Medicine’ button below</td>
<td>4. If there’s an allergy interaction, then system should pop-up an alert message for allergy interaction. Fig.3-Test No.11</td>
</tr>
<tr>
<td>5. Click on ‘Continue to Prescribe Drug’ button</td>
<td></td>
</tr>
<tr>
<td>6. Select the relevant ‘Drug Name2’ from combo box under ‘Prescription’ section and enter drug, frequency, rout &amp; duration</td>
<td></td>
</tr>
<tr>
<td>7. Click on ‘Prescribe Medicine’ button below</td>
<td></td>
</tr>
<tr>
<td>8. Click on ‘Continue to Prescribe Drug’ button</td>
<td></td>
</tr>
</tbody>
</table>

**Expected Results:**
Test case screen 37: (Fig.1-Test No.11) Selecting Allergy1 and Allergy2

Test case screen 38: (Fig.2-Test No.11) Prescribing Medicine1

Test case screen 39: (Fig.3-Test No.11) Pop up Alert Message
Test case screen 40: (Fig.4-Test No.11) Medicine2 added when “Continue Prescribe Drug” clicked

Test case screen 41: (Fig.5-Test No.11) Prescribing Medicine2

Test case screen 42: (Fig.6-Test No.11) Pop up Alert Message
Test No.12
Test Date: 
Summary: To test drug–allergy interaction feature
Description: When the doctor enters a medication in the system, if there’s an interaction, then the system should alert doctors in a pop-up message.
- Allergy1: Influenza Vaccine Live(KDC-5)
- Medicine1: Atorvastatin Calcium Oral Tablet 40 MG
- Allergy2: Acetaminophen(GPI) AND Medicine2: Acetaminophen Cap 500 MG

Pre-Condition(s):
- User should have access to the system
- User should click on “Prescribe Medication” request on the main CPOE screen

Post-Condition(s):
- n.a

<table>
<thead>
<tr>
<th>Test steps</th>
<th>Expected result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Invoke the prototype by enter below URL in the browser</td>
<td>1. Doctor should be able to access E-prescription prototype</td>
</tr>
<tr>
<td><a href="http://xxxxxxx/E-prescription/">http://xxxxxxx/E-prescription/</a></td>
<td></td>
</tr>
<tr>
<td>2. Select ‘Allergy1’ and ‘Allergy2’ from ‘Patient Allergies’ Section.</td>
<td>2. Allergies are selected in the ‘Patient Allergies’ Section. Fig.1-Test No.12</td>
</tr>
</tbody>
</table>
3. Select the relevant ‘Drug Name1’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration

4. Click on ‘Prescribe Medicine’ button below

5. Select the relevant ‘Drug Name2’ from combo box under ‘Prescription’ section and enter drug, frequency, rout & duration

6. Click on ‘Prescribe Medicine’ button below

7. Click on ‘Continue to Prescribe Drug’ button

3. Drug name is selected in the drop-down list.

4. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’.Fig.2-Test No.12

5. Drug name is selected in the drop-down list. Fig.3-Test No.12

6. If there’s an allergy interaction, then system should pop-up an alert message for allergy interaction. Fig.4-Test No.12

7. Drug name should be added to the prescription with ‘DRUG NAME, DOSE’ ROUTE, FREQUENCY, DURATION’.Fig.5-Test No.12

Expected Results:

Test case screen 44: (Fig.1-Test No.12)Selecting Allergy1 and Allergy2
Test case screen 45: (Fig.2-Test No.12) Medicine1 Prescribed

Test case screen 46: (Fig.3-Test No.12) Prescribing Medicine2

Test case screen 47: (Fig.4-Test No.12) Pop up Alert Message
Test case screen 48: (Fig.5-Test No.12) Medicine2 added when “Continue Prescribe Drug” clicked
6.1.2.4 Overall UAT process

The following shows the testing process steps from preparing until closing testing:

Figure 28: User Acceptance Testing Process
6.1.2.5 Data analysis

A total 72 test cases were done with 6 SUS form. Form test cases, three main variables were coded as test matrices. Test Metrics are the most important to measure the quality of the software and decide on the results of testing. The base matrices are used are the following: Total No. of Test cases Executed, No. of Test cases Passed and No. of Test cases Failed.

The Pass percentage of the executed test cases: \((\# \text{ Test cases Passed} / \# \text{ of Test cases Executed}) \times 100\).

The Fails percentage of the executed test cases: \((\# \text{ Test cases Failed} / \# \text{ of Test cases Executed}) \times 100\).

Excel sheet used to store and analyze the 6 SUS forms applied

![Excel sheet](image)

**Figure 29: Store and analyze the 6 SUS forms**

Using the following score formula to calculate SUS score for each test user, SUS scores have a range of 0 to 100 (Brooke, 1996):

\[
\text{Score} = \text{IF}(\text{Sheet1}!A2="", "", 2.5 \times (\text{Sheet1}!B2+\text{Sheet1}!D2+\text{Sheet1}!F2+\text{Sheet1}!H2+\text{Sheet1}!J2-5+25-\text{Sheet1}!C2-\text{Sheet1}!E2-\text{Sheet1}!G2-\text{Sheet1}!I2-\text{Sheet1}!K2))
\]
Researchers had some difficulties deducing what an individual SUS result means. They proposed adding an adjective scale of common nouns associated with usability such as SUS adjective metric from (Bangor, 2009).

![SUS Adjective Metric](image)

Figure 30: Adjective metric (Bangor, 2009)

6.2 Results

At the completion of each testing process, test results will be subjected to an informal review by the Testing team. All test results have been formally reviewed to ensure the testing has been satisfactorily completed and that the expected results were obtained.

6.2.1 Test cases results

The results show that all 72 test cases were successfully completed and passes. Test users completed 72 test case scenarios as detailed in the table 7.
### Table 7: Testing Report for test cases completed

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Test summary</th>
<th>Run date</th>
<th>Result # of Runs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>#Pass</td>
</tr>
<tr>
<td>1</td>
<td>To test drug-drug interaction feature</td>
<td>27 December, 2016</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>To test drug-allergy interaction feature</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>To test drug-drug interaction feature</td>
<td>29 December, 2016</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>To test drug-allergy interaction feature</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Total No. of Passed cases = 72
Total No. of Failed cases = 0
Total No. of Executed cases = 72
After track and record the test case results we defined the table of metrics as below:

Table 8: Testing metrics

<table>
<thead>
<tr>
<th>Testing Metric</th>
<th>Data retrieved during test execution</th>
</tr>
</thead>
<tbody>
<tr>
<td># Test cases Executed</td>
<td>15</td>
</tr>
<tr>
<td># Test cases Passed</td>
<td>15</td>
</tr>
<tr>
<td># Test cases Failed</td>
<td>0</td>
</tr>
</tbody>
</table>

% Test cases Passed = 15/15 *100 = 100%

% Test cases Failed = 0/15 *100 = 0

The value of Test cases Passed matrices calculated are 100% and the value of Test cases Failed matrices calculated are 0. That indicates a high score correctness and effectiveness of the system.

Figure 31: Test execution status
6.2.2 SUS Results

Excel sheet used to calculate the results of 6 SUS forms applied. The individual score and the average of SUS score is presented in Figure 32 and 33 below:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timestamp</td>
<td>SUS Score</td>
<td>Average</td>
</tr>
<tr>
<td>U1</td>
<td>80</td>
<td>84.16666667</td>
</tr>
<tr>
<td>U2</td>
<td>77.5</td>
<td></td>
</tr>
<tr>
<td>U3</td>
<td>87.5</td>
<td></td>
</tr>
<tr>
<td>U4</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>U5</td>
<td>92.5</td>
<td></td>
</tr>
<tr>
<td>U6</td>
<td>92.5</td>
<td></td>
</tr>
</tbody>
</table>

Figure 32: The SUS scores for each individual and the average SUS score

![Individual SUS Score and Average](image)

Figure 33: The chart of SUS score result

In Figure 34 the mapping between SUS score and the adjective metric shows that the system achieved its usability goals.
6.3 Discussion

After implementing the e-prescription support approach to facilitate clinical decision support in the drug prescription order process, the result is compared with those derived from the current experience-based approach, manual in the paper based on the human experience and knowledge to make the prescription.

In the current process of prescribing medication at paper request, if there is any drug–interaction case it may not detect by physician neither by a pharmacist, which lead to a medical error. If the pharmacist detects this error, the patient has to back to the physician to do the modification needed in the same prescription paper. The prescribe medication workflow is compared in the case of drug–interaction, with implemented CDSS as Figure 19 and manually without CDSS as Figure 35.
Figure 35: Current Prescribing medication order in the case of drug–interaction
The workflow above has shown that when doing prescription orders manually without CDSS, the correctness replace with accuracy was low. Even if the pharmacist figured out this error, the required time to modify this prescription was high (Efficiency was Low).

Findings of the evaluation in chapter 6 by UAT and SUS testing have shown that the implemented system increases the correctness, all test cases working correctly on preventing an error by preventing an error which reduces the medication error and the cost. In addition, it increases the effectiveness by saving the effort and the time for all: physicians, pharmacists and patients. The SUS score result shows how the user satisfaction with the usability of the system.

At the final stage of evaluation, the hospital will receive an overall testing score, and the scores will describe the performance of specific clinical decision support categories. Acceptance will ultimately reside with the medical staff as part of the User Acceptance Testing (UAT) process for software development. The hospital will be able to use these results to decide on implementing the full CPOE and CDSS and measure the error reduction frequency. They can test all the CDSS rules and implement it.

6.4 Summary

This chapter presents the evaluation process for the prototype system through using a two types of testing. First one defect testing by testing expert, second testing involving: the PM, analyst and physicians. The results of testing are recorded, analyzed and discussed towards understanding how the overall system increases the correctness of prescribing medication process in addition the highly satisfied of end users for using this system.
Chapter 7: Conclusion

7.1 Conclusion

In conclusion, the contributions of this thesis are that this research makes important contributions to healthcare Information Systems research and clinical practice. Also, it was used as an aid to understand the complexity of the healthcare system. This thesis has started with the motivation to develop a well-defined e-prescription system to facilitate clinical decision support concept in the drug prescription order process to eliminate the medication errors. Thus, getting the right answers of the main research question of what are the effective ways to eliminate errors of drugs prescriptions orders? Figure 10 shows the workflow for the proposed system.

This study had conducted an investigation on literature that studies the impact of CPOE on the patient safety in Saudi Arabia, such as the conducted preliminary study in hospitals in Riyadh with different CPOE system by Almutairi et al. (2011) which measure the CPOE and CDSS implementation in Riyadh. The following table summarize of related works that discussed the reducing medical error and implementing system:

**Table 9: Summarize of related works that discussed the reducing medical error and implementing system**

<table>
<thead>
<tr>
<th>Author</th>
<th>Study process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haux, 2006</td>
<td>• Present the main reasons for the cause of medication error</td>
</tr>
<tr>
<td>Haux, 2010</td>
<td>• Review the main consideration in transferring from</td>
</tr>
<tr>
<td>Author(s) and Year</td>
<td>Summary</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Al-Jeraisy et al., 2011</td>
<td>Identified the types of medication prescribing errors in the general pediatric ward and PICU at King Abdulaziz Medical City in Saudi Arabia.</td>
</tr>
<tr>
<td>Qureshi et al., 2011</td>
<td>Present multiple factors cause prescribing errors related to health professionals and health care systems.</td>
</tr>
<tr>
<td>Radley, et al., 2013</td>
<td>The study was conducted in the form of random effects of meta-analytic technique; show that CPOE is effective in reducing medication errors.</td>
</tr>
<tr>
<td>Alwan, 2010</td>
<td>The study evaluated the impact of CPOE system connected to the Pharmacy department</td>
</tr>
<tr>
<td>Bobb et al., 2004</td>
<td>The study in the academic medical center in Chicago conducted with pharmacists at a 700-bed facility</td>
</tr>
<tr>
<td>Rahim et al., 2015)</td>
<td>Discover the challenges of implementing CDSS</td>
</tr>
<tr>
<td>Shortliffe &amp; Sondik, 2006</td>
<td>Identified a model for information to be followed from Healthcare information system.</td>
</tr>
<tr>
<td>Eichner &amp; Das, 2010</td>
<td>Overview of the CDSS applications that can be used as a part of CPOE and electronic prescribing systems</td>
</tr>
<tr>
<td>DeLeon &amp; McLean, 1992</td>
<td>Using the DeLone and McLean model of information system to analyze the performance of the CDSS for medication</td>
</tr>
<tr>
<td>Al-Dahmash &amp; El-Masri, n.d.</td>
<td>Identified the software engineering methodology that considers the healthcare background of the end</td>
</tr>
</tbody>
</table>
user and the impact on the development activities.

Denver Health

- Implement CPOE and build an Intermediate layer modeling the vocabulary and orders
- Using CDSS by upload common laboratory, and radiology synonyms into the engine depending on the staff experiences

Kuperman et al., 2007

- Identified different CDSS types and database knowledge
- Identified consideration in CDS user interface design and message alert interaction

Ting, 2011

- Proposed a prototype system which integrated with data mining techniques that generates drug interactions alert and suggestions

The subsidiary questions were addressed by the prototype built. The first subsidiary question of ‘What are the required data and system components that could be implemented to incorporate patient safety during prescribing medication process? ‘was addressed by the configuration of parameters and related information for the patient and drugs on the interface which were considered in the design of the interface. In addition the integration of CDSS knowledge base for detecting an alert message.

The second subsidiary question of what are the challenges and limitations in applying the CPOE with CDSS system in health care fields? was addressed by eliciting requirement phase from interviews and questionnaires with stakeholder.

Therefore, the evaluation of the system was conducted and explained in chapter 6. The purpose of this evaluation is to validate that the proposed system answers the research question and fulfills its objectives. It has proved its effectiveness in answering
the main research question and improved the current process of prescribing medication order. In addition, the results showing that users were highly satisfied with the system.

When we adopted the e-prescription order in the CPOE doctor portal and integrate it with CDSS. We can assure the preventing of errors while prescribes medication which will improve the patient safety. The finding from evaluations, UAT and SUS show the success of different scenarios tested. In addition, user satisfaction on using this system. Comparing the current work flow in PSMMC for prescribing medication and with the new implemented system as we discussed in chapter 6 shows that the CDSS is more effective in reducing errors by detecting error alerts rather than hand writing paper what depend on physician’s knowledge and experience and may cause different errors.

This research improves the functionality of prescribing medication order by implementing CPOE with the e-prescription support approach to facilitate clinical decision support in the drug prescription order process. The main results of this research are:

- Identification of the requirements engineering including the use cases scenarios in order to demonstrate the new addition of the CPOE/CDSS implementation.
- Identification of the information that needs to be displayed in e-presentation screen
- Designing of the prescribe medication workflow
- Development of CPOE system design with the integration of CDSS.
- Development of database tables requirement
- Developments of the two main functions in our system are detecting Drug – Drug Interaction and Detect Drug – Allergy interaction.
• Development of the user interface that represents the prescription order details
• Identification of the challenges of implementing and using CPOE
• Results of the evaluation and test cases that confirm the research’s objectives which validated the proposed system and shows the user satisfaction.

Traditionally the way to implement CPOE is by using commercially available systems which may be faced difficulty on integrated with the current hospital information system and highly costs. Also, it will be difficult to use by the users. This is because the CPOE and electronic orders not considered the AS-IS workflow of paper-base order. For example: the prescribing medication order will be different in screen design, information entered and work flow. The implementing in house CPOE is customized to the PSMMC. The AS-IS order processes used with some improvements that has been discussed such as CDSS alerts. Thus, the added value of the research is: after the new implementation, when a physician request prescription he sends it to the pharmacy department. This current process compared with those derived from the current experience-based approach, manual in the paper based on the human experience and knowledge to make the prescription. The results are satisfying the needs by detecting the error and it saves time for the requester and patient.

At the final stage of this research, the hospital has received an overall testing scores that described the performance of specific clinical decision support categories. The acceptance of this project will ultimately reside with the medical staff as part of the User Acceptance Testing (UAT) process for software development. PSMMC can use these results in deciding on the full CPOE and CDSS implementation and purchasing the full package of CDSS provider.
The proposed system is tested for successful implementation of in house basic CPOE with commercial CDSS based, focused on prescribing medication order in the outpatient department in Riyadh, Saudi Arabia. A few hospitals in Saudi Arabia have recently introduced these systems using commercially available systems. This research will be the first of its kind in Saudi Arabia, especially in military hospitals under the ministry of defense. This is because most of the previous researches are from the US, European or Arabian countries where the cultural aspects are different from those in Saudi Arabia when it comes to patient treatment workflow.

7.2 Challenges and Limitations

Major challenges and limitations we faced in our research are as follows:

- Getting the Permission from the Academic Affairs in Medical Services Department (MSD) to conduct such research regarding their policy and procedures.
- Getting the Permission from “Research Ethics Committee” and “IT” departments in PSMMC to conduct such research related to the patient’s confidentiality.
- Long time to decide on Contacting with CDSS provider for the evaluation scope, the initial time was 40 days we have extended it to 60 days because we have included the annual leaves of our team and faced technical complexity.
- The scope was concerned with two types of CDSS.
- The sampling frame or size of the questionnaire in survey of research might not be significantly sufficient for justification, because of the limitation time and resources. The sample size should at least be of a size that could meet the significance level, selected carefully not randomly given the expected effects. Some studies argued that using small sample sizes are not meant to quantify the performance within a population but just to document the existence of an effect. However, large effect sizes are uncommon in the behavioral sciences (Winter, 2013; Anderson & Vingrys, 2001).
• Some physicians prefer not to use CPOE because they report that it is difficult to use and a waste of time.
• Lack of qualified health informatics experts and lack of well trained employees.

7.3 Future works

The future work of this research is to implement full CPOE orders with all CDSS types to be integrated with HIS and performing a further enhancement in the system interface and the user interaction with the system, especially for pop up alert messages. We will make it clearer and easier by having more declaration and URL links. In addition, using coloring alert message depends on the interaction level. Put more restricted actions for the “high level” interaction. The main future work focuses on finding more ways that can reduce medication errors and implement all CDSS types in order to improve the CPOE system.
References

- Aghazadeh, S., Aliyev, A. Q., & Ebrahimnejad, M. (2011, October). The role of computerizing physician orders entry (CPOE) and implementing decision support system (CDSS) for decreasing medical errors. In Application of Information and Communication Technologies (AICT), 2011 5th International Conference on (1-3). IEEE.
• Bouzguenda, L., & Turki, M. (2012, March). Coupling clinical decision support system with computerized prescriber order entry and their dynamic plugging in the medical workflow system. In Information Technology and e-Services (ICITeS), 2012 International Conference on (1-6). IEEE.


Appendix A

Interview Questions

The main similar questions were asked in all semi structure interviews was the following:

1. Are you using CPOE in PSMMC?
2. So are you planning to build complete CPOE system?
3. The CPOE type is commercial or in house system?
4. Is the CPOE can improve patient safety?
5. What is the current work flow for the prescribe medication for the patient?
6. The CPOE must be integrated to which health information systems
7. What are the required system components that could be implemented to incorporate patient safety?
8. Is there any CDSS implemented, any alert / recommendations?
9. Do think applying CDSS will decrease the error and improve patient safety?
10. What are the characteristics of CPOE that could improve the patient safety and Clinical Practices?
11. What do you think the effective ways to eliminate errors of drugs prescriptions order entries by implementing the CPOE?
12. What are the challenges and limitations in applying the CPOE in health care fields?
13. What are the future plans to improve CPOE?

The questions different from one interview to another based on the interviewee role: IT, physician or pharmacist. Some about the physicians job or pharmacist task or technical questions, only the IT staff can answer it.
Transcripts of the Interviews

Interview 1: IT

A: Are you using CPOE in PSMMC?
I: Until now we have been using it for reading and two e-orders request only. The doctor can browse the patient drug profile (all drug prescribed details), lab record (requested test and result) and radiology. Then the doctor writes the treatment field need, the subjects, symptoms, tests and prescribe medication and write all treatment plan. Also, he/she can request e-orders for laboratory and radiology, but the prescription request order still manually in paper. Later each department enters all this information into the mainframe: The medical record department, laboratory, radiology and pharmacy department, so the doctor can check any update later.

A: Are you planning to build full CPOE system?
I: Yes, and its in house development not commercial so we can do more customization for our use.

A: Do you think the CPOE could improve the patient safety?
I: Sure, especially if contains intelligent mechanism and display all patient history record so the doctor can have easy access for all data and can do better management.

A: What is the current workflow for the prescribe medication for the patient?
I: The doctor check patient drug profile from current system then prescribe the medication needed by write it with medication details (drug name – dose – rate – frequency- and any comments) on prescribing medication paper form. The patient takes it to the pharmacy department to dispensing the medication.

A: What do you think the effective ways to eliminate errors of drugs prescriptions order entries by implementing the CPOE?
I: If CPOE supporting improvement features, for example: select right drugs for the right diagnostic by implementing more rules and Alert for high risk medication or allergy.

A: The CPOE must be integrated to which health information systems?
I: The main system is HIS (Health Information System) with patient information database, LIS (lab Information System), PIS (Pharmacy Information System), Common Clinical Data Base, ICD 10. HIS (Health Information System) with patient information database.

A: What are the required system components that could be implemented to incorporate patient safety?
I: There is an intelligent rules /recommendation alert or it is clinical decision support system that can help the doctors during patient’s treatment.

A: So is there any plan to integrate CDSS with CPOE (with alert / recommendations)?
I: Yes in the improvement plan to advance the CPOE when finalize the implementation, because applying CDSS will decrease the error and improve patient safety. Actually, we started select one of the CDSS providers to have an evaluation scope before we purchase the system.

A: What are the characteristics of CPOE that could improve the patient safety and Clinical Practices?
I: Provide easy access for all updated patient’s data from all departments (information needed and results), Usability: ease of use, secure system, has all important intelligent rules, correct decision and recommendation alerts, fast and accurate error detect.
A: What are the challenges and limitations in applying the CPOE in health care fields?
I: From my experience work in hospitals, I think there are three main challenges: Integration between system Create rules for knowledge base and I think we will face challenges in Physician readiness.

Interview 2: IT
Analyst: Are you using CPOE in PSMMC?
IT: Yes, but partially, there is an ongoing project of “Doctor” portal with CPOE for electronic order entry. The system used by three departments and implement the log-in page and the main screen for diagnosis entry. There are some orders implemented such as Radiology request and laboratory request. Still the physician using paper for some orders not implemented yet in the CPOE, they are using Mainframe for retrieving all patient information that is helping them on patient treatment, they can access lab / radiology record checking the result (that entered from laboratory/radiology department not for ordering, also access patient drug profile entered by pharmacy department checking all drugs, old and new one and drug status.
A: Can the physician place an order for the patient drug profile?
I: No just for review the drug history for particular patient then write it on the consultation paper in drug prescription part, and then patient takes it to pharmacy to receive the medication.
A: How can all these information entered into patient file?
I: The pharmacy, laboratory and radiology updating patient file from their side, other related information (subjective, objective, diagnosis and assessments stored in patient file by sending all consultation paper to the medical record department who entering all information to the mainframe, the doctor later can find the update.
A: Is not considered Duplication work?
I: Yes, that’s why there is in progress project that allow doctor entering all these information directly on the screen, in addition to making all the request electronically.
A: What is the most developed in CPOE system?
I: The plan project is as continuous plan, developing log in screen for doctor by user name and doctor code with three main parts: chart (sub, obj. diagnosis and allergy), CPOE for ordering which will be for lab / rad/pharmacy and patient history. The assign departments to participate in the project are Nephrology, neurology and oncology
A: Is the CPOE can improve patient safety?
I: CPOE is electronic order services so yes by the CPOE the users can minimize the hand writing error and Loss of patient medical records. They can eliminate errors of drugs prescriptions order entries by implementing the CPOE by Allergy store checking Drug interaction by implementing the CDSS.
A: Is there any features support checking the prescription errors?
I: No, it is on a pharmacist side by checking the mainframe manually
The Pharmacist should detect the error, depending on pharmacist experiences in this field, to decide which conflicts!
A: **What is the current workflow for the prescribe medication for the patient?**
I: The patient enters the clinic and physics start examining patient decide what is the diagnosis and enter it in the encounter form (which include patient name, number and triage reading: temp, high Wight .etc) and entering all the following: sub / obj / assessment, and prescription ordering. Then patient go the pharmacy with this paper.

A: **What about lab/ radiology orders? Same encounter form?**
I: No, the physician enters the request with another special form for each department.

A: **To which health information systems the CPOE must be integrated?**
I: The screen about CPOE and all past patient visit details and the order services: Radiology, Laboratory and Pharmacy.

A: **What are the required system components that could be implemented to incorporate patient safety?**
I: In the addition of all parts in screen what we mentioned before, there is a sub systems to implement CDSS Company can be integrating, they request the all medication database in the pharmacy department, and then they map it to the cdss rule they have. Later we can integrate and have the correct recommendations and alerts all of these which can reduce and avoiding prescribing errors.

A: **What are the characteristics of CPOE that could improve the patient safety and Clinical Practices?**
I: The CPOE should support HL7 msg so can communicate with all departments systems and integrated with centralized database.

A: **What are the challenges and limitations in applying the CPOE in health care fields?**
I: Some physicians prefer not to use CPOE they prefer the paper based, integration between system, development cost and central sterilization services department.
Interview3: Physician

Analyst: What kind of system you are using to treat the patients?
Physician: We are using paper based “Encounter form” to write all the treatment needed and the prescription. For the lab order, radiology or other orders, we will fill the related form request. For the patient information, we should access the patient profile in mainframe just for retrieving the information

A: Are you using CPOE?
P: There is a new in house system for CPOE that should contain all information and e-requests needed, but not used for all clinics yet

A: What is the current workflow for the prescribe medication for the patient?
P: We received the patient from nurse after he do the registration at the clerk’s desk and waiting for the call. The nurse taking vital signs of Patients and we ask the patient about symptoms, to diagnose his problem and do the treatment needed. If prescription needed, we can review the patient profile in mainframe to check the drugs and the write the order in paper request and give to the patient.

A: What are the prescribe medication details you entered?
P: Drug code, drug name, drug dose needed, the route, frequency, duration and can write any comments related to this drug.

A: Is there any errors may occur while prescribe medication?
P: The errors caused because of lack for the information that could effect on the prescribed drug we have to carefully check this information. For example, female patient if pregnancy or not, the patients age, patient’s allergy and previous medication list.

A: What is the most common error you faced?
P: The harmful error is patient pregnancy interaction need drug interaction, but what are not detected usually is the drug drug interaction.

A: What do you think the effective ways to eliminate errors of drugs prescriptions order entries by implementing the CPOE?
P: If there is one place contain all patient information needed in a clear way. Site or list contains all drug interaction rules; we can access and check the drug we need to prescribe.

A: Is the CPOE can improve patient safety?
P: Sure, since its store all information needed to review before any electronic order request. Also, if the drug interaction rules implemented .All these help in decreasing the errors and improve patient safety.

A: Is there any communication with pharmacy? Is there a double check from their side and how they contact you?
P: This is one of a problem we faced. After the pharmacist checks the request, who check it manually depend on his experience. The patient has the responsibility to back to the doctor in order to modify the prescription.

A: What is the difficulty of using electronic order?
P: There will be resistance from some doctor to use an electronic device and writing form keyboard.
Interview 4: Physician

Analyst: Doctor tell us first of all the systems you are using in PSMMC?

Physician: For patient examination, we are open the mainframe from our PC’s to Browse the patient information needed, there is different codes and access for each department. Also, we can use Oasis, PACS, sick leave and other systems for different purposes. Also the doctor portal developed which contain basic information about patient and electronic order for laboratory and radiology requests. But still not fully implement and not used by all departments.

A: And which systems are you used for prescribe medication?

P: Now still we are depending on paper prescription request, I think here is a plan to adopt in doctor portal such other order we have, laboratory, radiology, admission and theater.

A: What is the current workflow for the prescribe medication for the patient?

P: The patient comes to his appointment and register in clerk’s desk. The nurse calls the patients to enter the clinic. We examine the patient and request the order needed, which includes the prescription order. We writ it manually in the prescription order paper. The patient takes his copy to submit it to the pharmacy.

A: Is there any errors may occur while prescribe medication?

P: Yes, that’s why we have to check all the drugs for patient history and the current drugs he have. Check all the patient demographics with the new drug. Also prepare our self to learn all drug interaction rules to avoid any errors might happen.

A: So what do you think the effective ways to eliminate errors of drugs prescriptions order entries by implementing the CPOE?

P: I think the doctor should be aware of all drug interactions or there is an intelligent applications have these rules and alert the doctor if there is any error detected

A: Is the CPOE can improve patient safety?

P: If the CPOE assures to centralize all accurate patient information needed and can prevent any error might happen then improve patient safety.

A: What are the prescribe medication details you entered?

P: We enter the drug name using drug code or drug generic name. Then complete the instruction by filling the route, dose, frequency and duration.

A: What is the most common error you faced?

P: Drug Allergy or drug –food interaction, if the doctor didn’t check the patient allergy or the patient’ allergy itself not updated. Also Drug – drug interaction and many types.

A: Is it impacts on patient safety?

P: Sure, these errors reduce the patient safety and quality it may casus patient die.

A: How we can make the system helpful and easy to use?

P: There is many ways for example, browse clear information with different tabs, The entries will be dropdown list if possible, contains recommendations and automatic validation.

A: Any communication with pharmacy? Is there a double check from their side and how they contact you?

P: The pharmacist should review the form after receiving from the patients against any error. If there is any modification needed, the patient return to us to change it. In some cases time the pharmacist can change it by the comity they have but after they take the permission from the doctor by calling him. I think this is a long process.
Interview5: Pharmacist

Analyst: What kind of system are you using?
Pharmacist: Pharmacy system that connects the patient profile (drug info) and drugs system for the drug stock and all drugs managements. Pharmacist updates the patient profile and check patient history.

A: How did you receive the prescription? What is the workflow?
P: The patients come to the pharmacy with encounter form (pharmacy copy), hand writing paper contains drug name and prescription details, all other info needed for diagnosis and vital signs reads that could help on review and dispense the medications. In addition, the doctor details.

A: So there is no checking by the system?
P: No, the prescription reviewed by the pharmacist

A: What if there is any modifications need?
P: If any changes needed because drugs not available or available partially, so we contact doctor by return the prescription with a patient or by phone to change the drug to other one. We can suggest particular drug sometimes, then if the doctor agreed we send the encounter by a patient to correct it. If disagreed for non-stock drugs, we ask the patient to come back later after 2 or 3 weeks.

A: Do you have any alert for drug interaction /allergy
P: No, we did it usually depend on pharmacist experience and upon the pharmacist’s knowledge

A: What is the most common error you faced?
P: Drug –drug interaction because it is difficult to detected and other types such as drug –dosing and Drug –allergy interaction.

A: What are the major problems you have?
P: Drug interaction not easy detected and taking long time to check the all prescription against all drugs interaction types. Also, there is a kind of drugs can be prescribed by consultant doctor, depending on his specialty, so we need to control this issue electronically rather than handwriting.
Questionnaires Form

Princeton University

Research title: Implementing CPOE integrated with the Pharmacy system to reduce medication errors

Dear Participant,

You are invited to participate in our survey implementing Computerized Physician Order Entry (CPOE). The idea of this research is to investigate the effective use of the implemented CPOE in Prince Sultan Medical Military City in Riyadh in reducing medication errors and Measure the implementation of CPOE system with improved features. In this survey, you will be asked to complete a questionnaire about the CPOE and it will take approximately 10 minutes to complete the questionnaire. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. For analysis purposes, your information will be coded and only the codes will be used in presentations of the data. Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any time. It is very important for us to learn your opinions.

Thank you very much for your time and support. Please start with the survey now by filling the following questions.

Q1. What is your gender?
- [ ] Male
- [ ] Female

Q2. Which category describes your age?
- [ ] 18 - 24
- [ ] 25 - 34
- [ ] 35 - 44
- [ ] 45 - 54
- [ ] 55 - 64
- [ ] 65 or older
Q3. What is your post?

☐ Physician

☐ Pharmacist

Please specify your specialty: __________________________

Q4. How would you rate your overall level of satisfaction with using computerized order entry (CPOE)?

☐ Highly satisfied

☐ Somewhat satisfied

☐ Neutral

☐ Somewhat dissatisfied

☐ Highly dissatisfied

Q5. How much do you rate CPOE on the following attributes? (5) strongly agree

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<tr>
<th>Order entry reduces patient care errors</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<table>
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<thead>
<tr>
<th>Order entry improves the safety of care I provide</th>
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<table>
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<table>
<thead>
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<th>4</th>
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</tbody>
</table>

154
Q6. At which stage the most medical error may happen?

- [ ] Diagnosis
- [ ] Lab ordering
- [ ] Prescribe medication ordering
- [ ] Others (please specify): ___________________

Q7. Do you think integrated the clinical decision support system (CDSS) with CPOE can improve patient safety? [CDSS given recommendations and alerts for an errors during clinical ordering]

- [ ] Yes I feel that I can benefit from improving order entry by CDSS
- [ ] No it will not improve

Q8. What is the challenge of using CPOE?

- [ ] The order entry system is not easy to use
- [ ] Compared to paper ordering, order entry slows me down
- [ ] Both
- [ ] Other (please specify) :
  __________________________________________________________
  __________________________________________________________
  __________________________________________________________

Q9. Do you have any recommendation/suggestions? (Write in proper sentence)

__________________________________________________________________________

__________________________________________________________________________

If you have any further questions or queries please contact:
reemaalhelwah@gmail.com
Questionnaire responses

Q1. What is your gender?

Q2. Which category describes your age?
Q3. What is your post?

Q4. How would you rate your overall level of satisfaction with using computerized order entry (CPOE)?
Q5. How much do you rate CPOE on the following attributes?

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<tr>
<td>Order entry gives me the information I need to write better orders</td>
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</tr>
<tr>
<td>Order entry improves the quality of patient care</td>
<td>3.94</td>
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</tbody>
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Q6. At which stage the most medical error may happen?

- Prescribe medication ordering: 62.86%
- Lab ordering: 11.43%
- Diagnosis: 26.71%
- Other: 0.00%
Q7. Do you think integrated the clinical decision support system (CDSS) with CPOE can improve patient safety?

Yes I feel that I can benefit from improving order entry by CDSS: 88.24%
No it will not improve: 11.76%

Q8. What is the challenge of using CPOE?

The order entry system is not easy to use: 26.59%
Compared to paper ordering, order entry slows me down: 26.47%
Both: 50.00%
Other: 2.94%
Q9. Do you have any recommendations/suggestions?

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<td>CPOE must be used as soon as possible in order to prevent error and improve the patient care quality</td>
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<tr>
<td>04/04/2016</td>
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<td>apply CPOE to all hospital</td>
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Appendix B

System Usability Scale (SUS)

<table>
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<th>Strongly disagree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I think that I would like to use this system frequently</td>
<td></td>
</tr>
<tr>
<td>2. I found the system unnecessarily complex</td>
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<tr>
<td>3. I thought the system was easy to use</td>
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<tr>
<td>4. I think that I would need the support of a technical person to be able to use this system</td>
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<tr>
<td>5. I found the various functions in this system were well integrated</td>
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<tr>
<td>6. I thought there was too much inconsistency in this system</td>
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<tr>
<td>7. I would imagine that most people would learn to use this system very quickly</td>
<td></td>
</tr>
<tr>
<td>8. I found the system very cumbersome to use</td>
<td></td>
</tr>
<tr>
<td>9. I felt very confident using the system</td>
<td></td>
</tr>
<tr>
<td>10. I needed to learn a lot of things before I could get going with this system</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C

MSD Approval

سلام عليكم ورحمة الله وبركاته

١. خطابكم رقم (٥/٠٠) وتاريخ (١٣)١٩١١

٢. نحن نستطيع بأن نعتذر عند تكوين نسخة من الإستبيان.

٣. إذاً، إبلاغ البحث بإعداد نسخة من الإستبيان، بمكتب المساعد للمستند التعليم والتدريب.

٤. يجب المحافظة على توقيت نسخة الإستبيان المكونة من (٤) صفحات وتحكم بشكل متساوي.

٥. يجب عدم التصوير الإستبيان بعد النعمة وعدم تسليمها لغير المعنيين.

٦. يجب على المشرف أن يعتذر عدم استخدام الإستبانة وتباعاً لغير إشارات البحث وعدم

٧. يجب أن يتم إبلاغ الإستبيان، في حال الانهيار، من الدراسة، وفقًا لإجراءات إحلال الوثائق

٨. إبلاغ

٩. السلام عليكم

แสนاً مدير مدينة الأمير سلطان الطبية المصرفية بالبحوث م.

مشرف بن علي المري

١٠. السلام عليكم.
Information Technology Department Approval

Title of the Proposal: Implementing Cybersecurity Measures

Investigator’s Name: [Redacted]

Date: [Redacted]

To: The Chairman Research Committee

Greetings,

We consent for the above mentioned research study to be conducted in our section / department. Please be advised that [Dr/Mr] is the administrative supervisor of the investigator.

Best regards,

The above mentioned research study is not feasible to be conducted in our section/department due to the following reasons:

[Redacted]

Name of Director/Head and Signature

Department/Section

[Signature]

[Redacted]