Ubiquitous Electronic Medical Record (EMR) for Developing Countries

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UBIQUITOUS ELECTRONIC MEDICAL RECORD (EMR) FOR DEVELOPING COUNTRIES

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ABSTRACT
UBIQUITOUS ELECTRONIC MEDICAL RECORD (EMR)
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Around the globe, Healthcare Information Technology (HIT) has been evolved either by governments or healthcare providers. The utilization of these technologies has resulted in the improvement of healthcare services all over the world. This evolution has been characterized by availability, reliability, serviceability to patients, and has been enhanced with increased cost and time efficiency. As such, new systems and terms have been established. Electronic Medical Record (EMR), which can also be used interchangeably with Electronic Health Record (EHR) is considered to be the main transformation in healthcare information technologies. EMR has been aimed to reduce and eliminate existing paper based approaches.

Many countries have adopted the use of EMR systems all over the world. However, these systems differ from country to country even though they serve the same purpose. The differentiation of implementing the EMR system often leads to incompatibility, which complicates cooperation between healthcare providers, and also compromises the efficient use and analysis of data that can be gathered from different locations or systems.

This thesis highlights and addresses the implementation of EMR on cloud-based systems to enable improvements in HIT. In particular, the scope of this research focuses on the use of EMR or EHR in Saudi Arabia, and establishes clinical information transaction standards that can be easily adopted by the different EMR application architectures available. Furthermore, the implementation of a cloud-based system is proposed for standard EMR to be used by both public and private healthcare providers in Saudi Arabia. The advantage that cloud technologies facilitate is the availability of data regardless of the patient, clinician, or physician's location. Similarly, these technologies enable a linkage and utilization of the Health Information Exchange (HIE) by healthcare researchers and providers to invest in data through online and offline cooperation. Support for the standardization of the EMR system on cloud-based technology will minimize or at best prevent human's errors, repetition or duplication of records, and reduce cost of operation and time.

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CHAPTER 1: INTRODUCTION

Essentially, an Electronic Medical Record (EMR) is defined as an electronic record of health-related information on a person that can be created, obtained, managed and operated by authorized health providers. The concept of EMR has evolved since the early 1970s. In the early 1970s, the EMR was a basis for investigation so as to improve medical health care [1]. The aim was to store medical data and other records for patients for long periods of time, and at the same time ease the accessibility of such information. Currently, EMR has been implemented in many different hospitals and clinics around the world. What drove the implementation of this system was to improve the quality of patient care and reduce medical errors. Moreover, EMR provides facilities that not only improve the safety of the patient but also enhances workflow in healthcare facilities [1]. It has also been argued that the whole filing procedure has been redefined through EMR as patient documents can be easily recorded, linked, and retrieved for current use and future reference. The scope of this thesis is aimed towards analyzing the health care system in Saudi Arabia and the process of designing and implementing a standard EHR system platform using cloud technology.

Health information technology has developed around the globe. Different countries embrace different types of EMR systems. The manner in which the system is used varies from one country to another. There are numerous differences and similarities in the healthcare system of Saudi Arabia compared to other countries in the world. In the U.S., the HITECH Act, signed in 2009, gave healthcare providers incentives to implement EMR technology. The adoption of the technology in the U.S. was mainly

aimed towards improving the quality of health services. Furthermore, the U.S. government, through the Patient Protection and Affordable Care Act, has increased health insurance to millions of uninsured Americans [2]. Despite issues such as optimization, implementation, cyber security and interoperability that have thwarted the implementation of EMR technology, there has been a strong push in the U.S. for its implementation. Implementation in the U.S. has been given a higher priority as compared to Saudi Arabia. Its average adoption rate as at July 2013 was at 69%.

The United Kingdom has also been in the forefront championing for the adoption of the technology. For instance, in 2002 the National Program for IT wanted to create a national electronic health record system to be used in the entire UK. The aim of the project was to eliminate the problems of interoperability between the different EHR systems [3]. The UK government tried to implement the complex system by contracting four companies to create a national system that would allow the state attain interoperability in the system. However, the project was not adequately implemented, due to cost and time constraints.

In France, just as in the United States, most citizens are medically insured mostly by their employers. Based on the 2000 Universal Health Coverage Act, everybody has access to healthcare. Furthermore, France has a competitive system of providers, the SHI (statutory health insurance), which is tasked with the responsibility of ensuring health care coverage is universally applied, and the Universal Health Coverage Act extends coverage to citizens that do not qualify for SHI coverage. France has successfully implemented EMR with a current adoption rate at 67% [3]. Despite the United States having a higher successful implementation rate, which is currently at 85%, reports

indicate that France has a stronger hold on HIE, privacy laws and interoperability that is capable of creating enhanced frameworks for future electronic health records systems to successfully connect and operate with more complex capabilities. Another difference between the medical system of the U.S. and France is that France only adheres to national medical privacy laws, which has enabled it to have harmonious regulations and rules. Furthermore, the country has a centralized, top-down system that makes it easier to adhere to the national security and privacy laws and regulations. France, through the Health Insurance Portability and Accountability Act of 1996, has also been able to address issues of cyber security.

In India, the healthcare system is made up of both public and private hospitals. The country has a target of providing better healthcare. This is evidenced in some of the projects that the country has implemented in a bid to improve healthcare provisions. For instance, in 2011 the Integrated National Health system was started by the Indian government to provide universal quality health services by the year 2020[3]. The country, despite embracing the use of EMR, is behind other countries such as France and the U.S.

In Saudi Arabia, most healthcare service providers use the manual system of patient record keeping. Only a few hospitals have embraced the use of EMR technology. Some facilities have only a partial EMR system with limited functionality. A large percentage of healthcare services are provided by public hospitals. In consideration of the increased benefits of EMR, Saudi Arabian hospitals are being encouraged to implement the technology. Public hospitals in Saudi Arabia have started adapting and implementing the EMR; however, connections between the different systems in these

hospitals is missing, thereby making it difficult to link patient records [5]. As a result, patients are unable to access a full and synchronized health record, because the record in Hospital A is different from the record in Hospital B [4]. The lack of common patient databases is a problem for patients, who have to go through the long processes of filling out forms for information to different systems of each hospital they attend [5]. As a result, this leads to repetition in records and results in patients having to undergo unnecessary tests already performed at previous visits to different hospitals.

Based on the current state of medical record information access and the push for greater technology adoption, this thesis is a basis for developing a standard platform in Saudi Arabia for EMR using cloud technology. A standard platform will lead to more efficient methods for exchanging health information. The final findings of this research will provide the Saudi Arabian government the guidelines for the implementation of the EMR through the Saudi Health Ministry. In Saudi Arabia, hospitals are either public or private. Both are controlled by Ministry of Health (MOH). By adopting the solutions offered in this thesis, the health ministry will be able to provide high quality, more efficient services through advanced technologies in an updated IT platform. Such a platform will not only mimic other successful platforms used by other countries, but also provide the much-needed communication between hospitals in an easy, fast, and cheaper means of exchanging patients' records.

It is undoubtedly clear that having a single integrated national EMR system can accrue tremendous improvements. Most successful countries, such as France, which have the most harmonious and well-integrated healthcare systems, attribute their success to the implementation of the EMR system [3]. Currently, Saudi Arabian healthcare

facilities are still implementing the manual health record system, with only a small percentage of the hospitals embracing the new technology. The resultant impact of failure to implement the technology includes reduced effectiveness and efficiency in service provision. UN involvement, misplacement of patient records, and entry records are included in the many existing challenges of efficient medical service [6]. These challenges can easily be prevented or eliminated through the use of EMR technology. Therefore, there is a great need to establish a national EMR system through which any authorized healthcare provider and the patient can access medical records at any time and in any healthcare facility.

The goal of this research is to design a standard platform for a national EMR that meets all the needs of patients and healthcare providers in Saudi Arabia, and propose its deployment as a cloud-based system. Exploring the use of a unified central database repository and access through a web-based service for physicians, patients, and hospitals employees using web technologies or mobile applications are the main objectives of this thesis. Furthermore, this research will provide some future ideas about the implementing additional advanced technologies, such as Bring your own device (BYOD), or integrating fingerprint identification into the Personal Health Record (PHR).

CHAPTER 2: MOTIVATION

As of now, the health information technology (HIT) in Saudi Arabia is at its inception stage and is considered preliminary. The primary motivation for Saudi Arabia to adapt to this new technology is to experience the benefits other developed countries are accruing from the use of Electronic Medical Records (EMR), PHR (personal health records) as well as other new innovations that are associated with joint care, a single point of healthcare access to clinical as well as demographic information, patient safety, as well as hospital support services by developing a standard EMR system that is based on cloud technology [7].

The research is motivated by the need to replace the paper-based medical records currently used by most healthcare facilities in Saudi. In today's information age, paper-based medical records are seen as incomplete, sometimes hard to read since they are handwritten, fragmented in the sense that different information is in different parts, and it is not organized as a centralized information system [8]. Therefore, there is an increasing need to design and establish a standard EMR model based on cloud technology that will offer a centralized, shareable, accurate, and up to date record, which is potentially available at any location at any time through a rapidly retrievable information source. A properly designed EMR system can provide all the above needs. Moreover, the system has the potential for automating, configuring and aligning the flow of clinical operations. This will help Saudi hospitals to overcome the challenge of workflow fragmentations. Furthermore, it maintains information and provides a data trail that is systematic, thus has

the potential to ease medical audit analysis, quality assurance and research, disease surveillance and epidemiological monitoring. Consequently, it offers integrated support for multiple discrete care activities such as monitoring, decision support, electronic referrals radiology, electronic prescribing and results display.

This research is also motivated by the capabilities of the EMR systems that have revolutionized health service delivery in other developed countries such as Australia and the Netherlands [3]. Notably, these systems can obtain data at the hospital, integrate the data from both external as well as internal sources that can support healthcare providers in making informed and accurate decisions. The system enhances electronic connectivity and communication by offering a platform for secure, efficient and readily accessible communication between patients and providers, which enhance the continuity of care, service delivery, timely diagnosis and treatment, thus reducing the frequency of errors and adverse events.

EMR also has the capability for maintaining orderliness since it can accept data and store patient information regarding medical tests, provide for electronic prescriptions, eliminate the problem of handwriting legibility in records, and improve the speed of executing orders and reduce duplication. Also, it has the ability to manage results since it provides a platform where all healthcare providers participating in the treatment of patients from different settings can assess test results to increase the effectiveness of care as well as patient safety. Finally, the system enhances administrative processes as it employs computerized management tools, for instance, automatic scheduling systems, that enable timely care service to patients and improves a hospital’s efficiency.

2.1 E-government

Most developed and also developing countries are increasingly employing e-government to help in accelerating government processes, delivering a quality level of service to its businesses and citizens, enhancing transparency as well as increasing accountability and at the same time lowering costs. Primarily, e-government refers to a government's use of web-based internet technologies to foster access and delivery of government services and information to its citizens, employees, partners and other entities and agencies. Recently, Saudi Arabia has embraced e-government with the aim of making its government smarter, enhancing the efficiency of service delivery and also giving its population new tools to engage with the government [9]. By so doing, Saudi Arabian citizens are now expecting better, faster, cheaper and more accessible services.

In spite of early resistance to the e-government vision, the government of Saudi Arabia is now focused on the electronic transformation from the traditional manual system. In a bid to having the program implemented, the government came up with programs and strategies on how to go about the implementation processes. Their progressive implementation has won the nation awards and international recognition. In a bid to show commitment, some of the policies and programs put in place include:

- Pursuant to the Royal Decree (7/B/2427), which is dated 16/1/1424 H, the Ministry of Finance was instructed to proceed with the implementation of the e-government program.

- Similarly, the Ministry of Communication and Information Technology, under the Royal Decree (133) that was dated 21/05/1424 H, was instructed and given the responsibilities to manage, plan and develop the communication and information technology sector and also launching the e-government.
- Furthermore, under (7/B/33181) that was dated 10/07/1424 H, the Ministry of Communication and Information Technology was instructed and given the mandate to come up with a plan that would effectively and efficiently deliver e-government activities and procurement of the necessary resources [9].

These programs were made after realizing that it was important to incorporate and merge with forces from different areas of authority so as to incorporate with today's information-based society and establish new goals and objectives [9].

The Ministry of Communication and Information Technology (MCIT) and the Ministry of Finance partnered to establish the e-government program, named Yesser. The Yesser team continues to play an integral role in the implementation of e-government. It thrives on managing its activities by itself, reducing as much as possible any interference from the central government in the implementation of e-government, while at the same time ensuring there is a minimum level of coordination between the various government departments.

Through the above programs under the stewardship of Yesser, Saudi Arabia is ranked among the most advanced countries in the world concerning e-services. The Saudi Arabian e-government has reaped numerous global awards during its participation in different international events. The global awards won clearly indicates its leading role in the conversion of Saudi government agencies in pursuit of effective e-government.

Furthermore, its participation reflects the level of precedence given by Yesser to exchange distinct world experiments and implement the finest industry practices in Yesser projects and activities with the aim of sustainable development [10]. Some of the recent awards that the Saudi Arabian government has won include: the World Summit 2013 award, where its e-portal was ranked as the best at the world summit; the UN Public Service Award; the GCC e-government Award and government technology for Asian countries in 2009 [10]. Also, its e-transformation measurement methodology reaped a best government practice award in Asia. Its progressive global ranking at the world level regarding social e-participation based on UN measurement over the past five years from 2008 to 2016 have been 70, 58, 41, 36, and 44 respectively. This recognition clearly denotes how the government has been improving progressively over the years [10].

Based on this systematic progression of the e-government program, the country has great potential and the capability to actually implement an integrated EHR program in its healthcare centers. Furthermore, the global ranking is based on the e-programs the government is implementing; therefore, when it fully implements the EHR program, it is more likely to result in an even higher ranking. The Saudi government is also working on adopting systems on the cloud; this will also go a long way to foster the implementation of the EHR program. This thesis champions for the implementation of the EHR program, which when implemented, will help the Saudi government gain a higher ranking and greater world recognition. The success of the e-government program is further motivation towards the implementation of an EHR program.

2.2 Privacy and Security

The privacy and security of health care data is one of the most critical concerns for the countries that support exchange and sharing of electronic medical records as web services or mobile technology with cloud computing technology [11]. Individual companies have designed different EMR software solutions, therefore different hospitals use different versions depending on the software they have implemented. This differentiation of EMR systems causes weakness in security design and also makes the possible solutions more difficult. The hospitals use these systems through software providers and a provider may have lack of knowledge about protecting this data. In August 1996 in the U.S., President Bill Clinton signed the Health Insurance Portability and Accountability Act (HIPAA), which is United States legislation that provides regulations for providers concerning data privacy and security provisions for safeguarding medical information exchange [8]. However, in 2014, data breaches at EMR services occurred and around 3.9 million patients record were impacted [12].

In the proposed system design, the Saudi government, represented by the Ministry of Health (MOH) and the Ministry of Interior (MOI) will control the centralized data repository for EMR, which will give them the control over the data as well as the accesses and permissions. This central data repository for EMR will allow for easier management and grant more security than individual organizations. The privacy and security aspects will be guaranteed based on the fact that governments are more capable than individual companies to provide the best security solutions in the market and also make these solutions available whenever it is needed.

The implementation of the EMR system will not only enhance the efficiency and effectiveness of healthcare provisions. It would also enhance the level of patient privacy and security. The HIPAA security rule came up with measures that aid in safeguarding electronic health information with the aim of ensuring security, integrity, and confidentiality. There are specific security safety measures that are inbuilt in the EMR system. Some of the safety measures include the 'Access control' tools, such as PIN and passwords, to limit access to patient information by persons authorized for the information, such as the patient's nurse or doctor [13]. There is also the encryption of stored patient information. This means that the information cannot be understood or read by just anybody, but rather only by individuals who have the ability to 'decrypt' the encrypted information through the use of a special 'key' that is only available to authorized persons [14]. There is also the 'audit trail' that records persons who accessed information, as well as any changes made and when they were made. When a patient's information is accessed by authorized persons, the patient's doctors or nurse is required to notify the patient of a 'breach' of his or her health information. Doing this is important as it helps patients know if there is anything that has gone wrong with the safeguarding of their information. It also helps in keeping the healthcare providers accountable. Furthermore, based on the current HIPAA regulations, patients have rights with regards to their health information that is stored electrically. According to the regulations, patients have the right to access or request a copy of their medical health records at any given time. They can request for a rectification of any incorrect information or typographical errors made in their health records. They also have a right of receiving notification about the usage of the medical records and the type of

communication methods used by a healthcare provider. Furthermore, patients can also file a complaint, if they feel that there are violations from a healthcare provider, with the Office for Civil Rights [13]. These are some of the regulations put forth by HIPAA to help in ensuring that the privacy and security of patient information is guaranteed, therefore, enhancing the efficiency of the program.

Apart from the HIPAA regulations, there are also some privacy and security measures that are put in place with the specific healthcare facility. It is the mandate and responsibility of healthcare facility management to enhance its administrative controls. This can be attained by constantly and regularly updating procedures and policies, such as putting in place background checks for all its employees and also guiding employees through the strict security and privacy training process. It is also the mandate of a healthcare provider to ensure that it monitors the physical safety of the EMR systems. Similarly, this can be attained through measures such as accessing the list of the only the authorized users of the system, providing programmed software shutdown routines, and creating physically remote systems to persons that are not authorized to use the system. Supplying of personal identification numbers and passwords are also important as a security and privacy technique [14]. Furthermore, having exigencies in place for data restoration and recovery and also providing verification requirements and identification to all the users of the system are also some of the most effective techniques used by healthcare service providers to provide privacy and security to patient medical information.

2.3 Cooperation and Easiness

One of the greatest hurdles experienced in healthcare facilities is maintaining a cohesive interaction between the patients and the healthcare service providers. EHR can be used to improve interaction and communication. First, an EHR system provides a provision for electronic messaging between patient and the healthcare providers. It also enables patients to access their information at any time they so desire. This creates new possibilities that foster dialogue. When health service providers invite patients to view parts of the electronic chart on a computer screen, this not only prevents uncomfortable moments of idle silence that often accompanies EHR-based tasks but rather it also improves the relationship aspect of physician-patient communication in a manner that encourages patient activation in actual time [13]. Furthermore, EHR aids real-time interaction and communication with patients mostly during office visits, mainly through actual access to the patient data, enabling health service providers to communicate with patients rather than search for patient information from manual paper records.

Furthermore, the systems usually have online interaction platforms where the patient can easily seek for clarification or help from his or her home and get medical support from their physicians. The system enhances not only patient-doctor interaction but also doctor-doctor communication. A patient may have different doctors with different specializations. All doctors treating a specific patient all can have access to the patient electronic medical information. This helps them know the prescriptions provided by other health service providers to avoid prescribing medications that are

contraindicated. Furthermore, they are also able to interact with one another through the electronic messaging provided by the system.

Besides enhancing the interaction between the patient and the health service providers, the electronic medical health record system is economical to patients as it saves a lot of time and money. All the information the patient may need to know is stated in the system. Once a patient registers, all his or her information is kept in the system and can be accessed by authorized doctors or persons from all healthcare facilities within the country. Therefore, when a patient visits a healthcare facility, he or she does not need to register each and every time they visit the facility. They only need to show up; the doctor or the physician just searches for their medical health records from the system and attends to the patient as required. This is opposed to the traditional system that would take a long time, looking for the patient's files and manually entering information. Money is also saved as patients only visit health facilities upon their doctor or physician request. Furthermore, they can book for appointments from the system, thus, increasing the efficiency and effectiveness of service provision. In the past patients had to physically visit the healthcare facility to get medical attention; however, with the advent of the EMR technology patients can now book appointments for medical checkups.

The scenario that a Saudi patient follows in health care centers or hospitals requires them to fill in their medical information every time the patient visits a different place. Also, repeating the medical tests and x-rays mean a long process for the patients and physicians, which in turn costs the SA country more additional expense. When an EMR system is centralized, the exchange of pertinent information between hospitals will make the connection and cooperation between hospitals and physicians about patient

care much easier and faster.

2.4 The Emergency Case and Health Care Researchers

The desire for any patient is to get immediate healthcare attention, especially in the case of emergency situations. Unlike in the past, when the patient had to be ferried to the hospital for medical tests, today with the advent of a centralized EMR system, healthcare practitioners can now provide remote medical attention. This adds more value to healthcare provision especially in the case of emergency situations. Today, many healthcare facilities within the emergency department have EMR systems, which aids in peripheral clinicians healthcare provisions. With patient information being easily accessible by healthcare providers in the EMR system, they can now carry out their activities remotely [15]. They are now able to retrieve patient information and attend to patients in the ambulance, car, or at the patient's home. Through this, they can save a lot of time that would otherwise be spent on traveling to the healthcare facility.

In the hospital, despite the fact that the use of a centrally positioned workstation provides greater visibility, it has its challenges. Physicians have to move frequently between various locations such as the nurse's workstations, patient rooms, and the central workstation to attend to patient's clinical needs and find their information. This constant movement of healthcare service providers increases not only physical effort but also increases mental effort due to many disruptions along the way [6]. Therefore, by having a centralized EMR system where the health care provider can have access to all patient information they need from a single point has reduced such kinds of movement

and a lot of physical as well as mental effort used. Apart from reducing mental and physical effort, a lot of time that could be spent along the hallways moving from one ward or room to another is reduced and saved thus, giving room for the healthcare providers to attend to more patients with less effort.

Most healthcare providers ascertain that EMR play an integral role in having a high-quality emergency department that fosters enhanced patient care. Currently, different types of medical records are being implemented and being used including dictated, handwritten, template, scribed and electronic medical records. It is the mandate of emergency physicians to play a lead role in the selection of medical record documentation components for the healthcare system [13]. Most emergency medical responders embrace the use of the EMR system over other medical record systems due to its effectiveness. They fathom that the system enables communication between providers, ease of data reporting and collection, discharge instruction communication, legibility, coordination of follow-up care and efficiency in the patient encounter continuum. They also state that when the system is successfully implemented, a high-quality emergency department medical record accurately captures the process of management, evaluation, medical decision making as well as disposition concerning a patient encounter [5]. Furthermore, EMR system facilitates quality improvement, quality assessment, risk management practices and meaningful use. Moreover, the system is always promptly available at any time.

Apart from playing an integral role in enhancing emergency cases, online EMR that is centralized helps in improving the quality of health research. This is due to the

availability of relevant information needed in completing a database in the diagnosing of diseases.

CHAPTER 3: CHARACTERISTICS OF SYSTEM SOFTWARE

One of the objectives of this project is to unify and eliminate the incompatibilities experienced by different EMR systems. Such incompatibilities prevent effective analysis, thus leading to inconsistencies of EMR data that is collected across the different systems.

Effective understanding of patients has been important in healthcare information technology (HIT). Thus, there has been constant revelation in the same including exchanging electronic medical records, personal health records (PHR), consulting about specific causes between different physicians, and using patients' data for research and studies of some critical diseases.

There have been constant differentiating factors in the use of EMR, thus leading to different ways of exchanging medical information in countries all over the globe. Some countries depend on healthcare providers who have control over the EMR or HER data. However, other countries have a centralized database repository for EMR owned by the government. Access and services are provided by the government to health organizations.

The focus of this project is to showcase the benefits of the implementation of a cloud-based infrastructure for EMR in Saudi Arabia. The characteristics of the project include enabling web-services access for patients and physicians anytime and anywhere, establishing a large data repository for EMR that is not available in traditional IT

environments, facilitating sharing of patient data, and improving the ability to analyze data.

Therefore, for an effective and high performance system that will supersede customers' expectations, the main characteristics that will be analyzed include: Operational characteristics, Transition characteristics and Revision Characteristics (see Figure 3.1) [16].

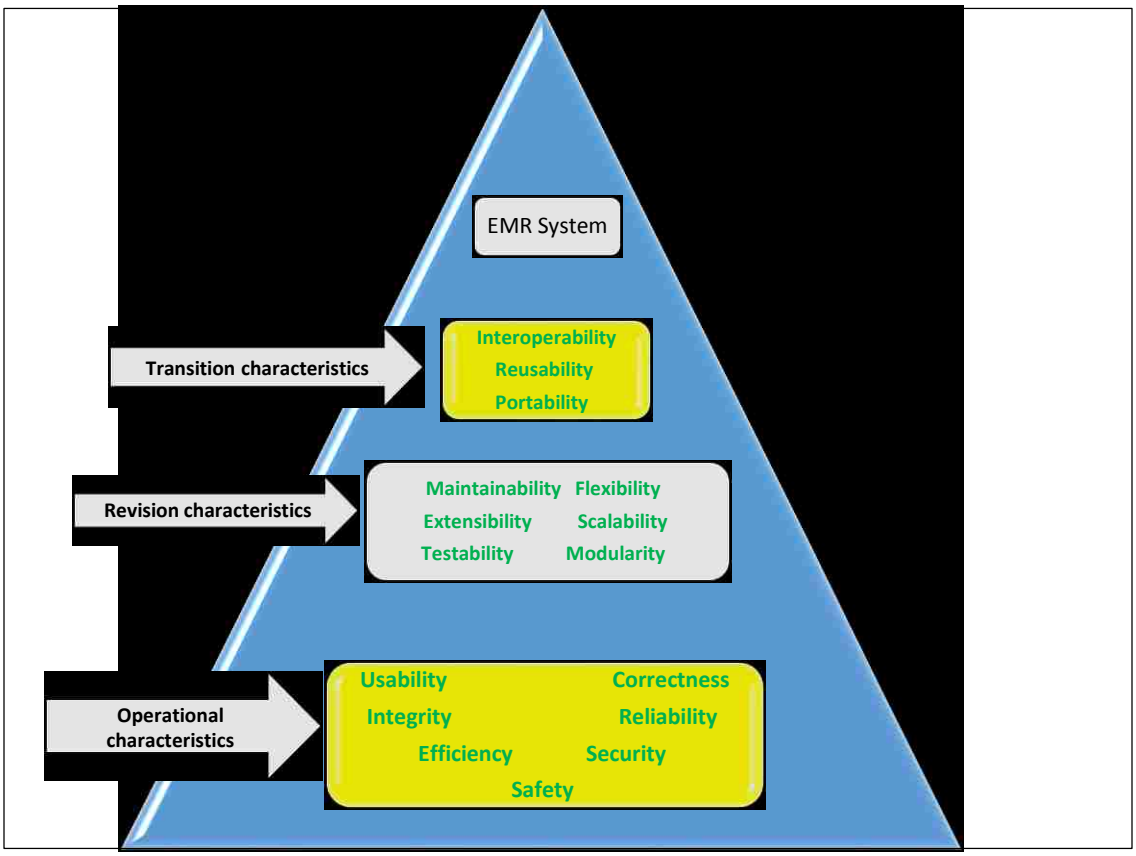


Figure 3.1 The three main characteristics of EMR system

3.1 System Operational Characteristics

System Operational characteristics include such things as system correctness, usability, integrity, reliability, efficiency, security, and safety. These characteristics are reviewed in detail below.

3.1.1 Correctness

One of the main areas of consideration before making an investment in an EMR system is to ensure it is correct, and therefore has a high level of accuracy and is highly reliable. As much as EMR systems are generally perceived to be highly accurate and correct, some are more efficient and accurate than others; therefore, caution should be taken in system design. Essentially, the first step is to collect patient's requirements for the EMR system. These requirements should be stated through user stories, following the agile development process. After user specifications are stated by creating user stories, the system should meet all those specifications to satisfy the correctness characteristic. The system should be able to accept patient information and be able produce accurate information when matched with the system information. Furthermore, the system should be able to make the information consistent such that when accessed from a different health facility, it displays similar results so that the information in one system is not different from that in another facility.

3.1.2 Usability

The usability characteristic simply infers to the ease of use of the system. Past research studies indicate that there have been numerous obstacles and barriers hindering effective implementation and use of these systems. Human resource barriers are indicated as the most prevalent barrier amongst all other barriers. Some of the other barriers highlighted include a lack of experience in using EMRs, low numbers of health informatics specialists and lack of knowledge of using EMRs [17]. All those barriers motivated us to take into consideration advising the use of EMR as a national, rather than institution-specific, system. To enhance usability, we advocate enabling multiple languages for the EMR system (especially Arabic), creating user-friendly interfaces, and ease of access to the system from anywhere and anytime.

3.1.3 Integrity

The issue on the integrity of any EMR system is a widely debated issue around the globe. Despite the EMR system being recently adopted in Saudi Arabia, a lot of issues have been raised regarding the level of integrity of the system. Some of the integrity issues raised about the system regard security and privacy of patient information. However, according to the fact that our suggested system will develop and work using cloud technology, the integrity of system will be able to protect and control the data access for authorized users. The system will incorporate a lot of security and privacy measures, such as use of passwords and restricting access of unauthorized

persons. All integrity issues regarding the use of the system will be dealt with. Therefore, system adoption by the Saudi government, and especially with cooperation between MOI and MOH, will decrease concerns regarding system integrity.

3.1.4 Reliability

Undoubtedly, the desire of any user is to have a reliable system that does not result in inconvenience. This system has put in place all the required measures to ensure that the system is more reliable and accurate. First of all, as a cloud-based system, it will be of high performance and quality, and will operate 24/7. Therefore, there will be a need for two EMR systems that are identical and parallel; if one of them goes down, the other serves as a backup (see Figure 3.2). By having two systems in place, when one system breaks down, the other system automatically picks up, thereby eliminating inconveniences that could arise.

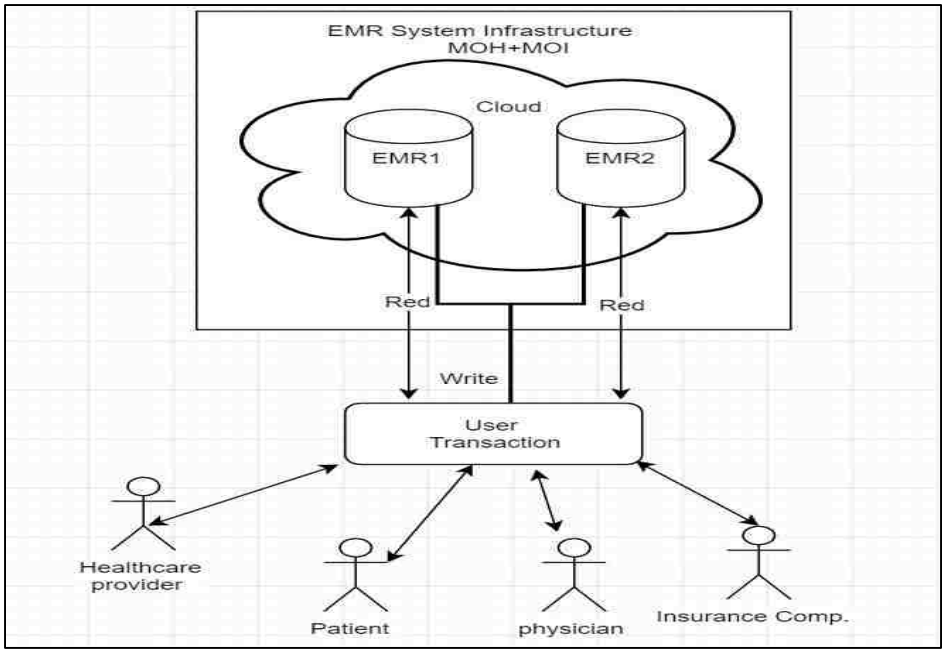


Figure 3.2 The suggested solution to satisfy the reliability characteristics of EMR system

3.1.5 Efficiency

The desire of every user is to have an efficient system that meets and exceeds their needs and wants. The implementation of EMR system as a national system requires high efficiency based on the huge number of users and transactions that system will handle per second. Therefore, using the EMR system on the cloud, as this research suggests, will enable software to use the system resources in properly efficient ways, such as making effective use of the storage space based on demand.

3.1.6 Security

It is important to note that the security of patient data is key in the implementation of any EMR system. Thus, the implementation of the EMR recommended in this work will also be based on the fact that it has to secure the patient's records from unauthorized access. This system will involve complex programming that will see to it that there is a high level of security to prevent breaches. Therefore, the idea of adopting EMR system through the Saudi's government, represented by MOH and MOI, will lead to a fully protected system. MOI has already adopted other security-critical systems on cloud, such as e-passport, which means they have a ready cloud infrastructure with security systems set up. Nevertheless, an added security protocol will be put in place to strengthen this.

3.1.7 Safety

Safety issues go hand in hand with security concerns. It is an essential characteristic of any system. This system will be made in a manner so that it guarantees total security for users of the system. Around the world EMR systems have been adopted locally, which have in turn raised different issues, such as safety and privacy. Our system is a cloud-based system, which means the host of our system will be responsible to take a backup and ensure that our system will be available under any environmental circumstances. Existing safety protocols by the Saudis (MOI) are taking an automatically data backup as daily, monthly and yearly to satisfy the safety of systems. Moreover, the

physical outlook of the system is metallic and very strong and durable. The users will also be inducted on the usage of the system, including the necessary security measures how to best minimize accidents.

3.2 System Revision Characteristics

In general, revision characteristics are more about the interior quality of the system. Five main characteristics fall under revision, including maintainability, flexibility, testability, scalability, and modularity. Each is discussed below.

3.2.1 Maintainability

Our system is a cloud-based system, which means the cost of maintenance will decrease according to the fact that the host of EMR system will be responsible for it. Also, the system would be developed using Agile software development process, where various iterations delivered with customer changes requested will make sure that it is a high performance system designed efficiently for less required future maintenance. Therefore, the system being advocated in this research will be of high maintainability.

3.2.2 Flexibility

The flexibility of any system plays an integral role on the number of uses of the same system. Our system seeks to be highly flexible and incorporate diverse usage. The main reason to develop our system using Agile development process is to make EMR

system more flexible to change. Agile principles welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage. Therefore, our system will be more flexible and acceptable to change more than others.

3.2.3 Scalability

Scalability is an important consideration in our proposed system. This was to ensure that future system upgrades were easier assuming that the number of users using the same system will increase. Thus, the system grants an opportunity for future expansion. For instance, this system seeks to serve an entire Saudi Arabian nation. This system is an improvement of the system used in specific health facilities.

3.2.4 Testability

During the development of this EMR system, heavy testing was done. In this thesis, a test plan has been included in the latter chapters to highlight the importance of testing using agile development process. Every step has been tested to ensure that the system has little to no flaws so as to ensure it is user friendly and functions effectively. Thus, the ultimate goal of the system is to ensure that the end users and customer are satisfied and that their expectations are met.

3.2.5 Modularity

HIMSS analytics created a model to measure the adopting of EMR system [25]. EMR system is considered as a fully functional system when it is implemented and should be able to perform the entire hospital functions automatically. These functions include but are not limited to document imaging, data warehousing, and medical images within its EMR environment. When the system combines all the independent functions together, level or stage 7 in the HIMSS model could be achieved, and our system will have high modularity.

3.3 System Transition Characteristics

To consider a system as a high quality system, transition characteristics must be met, including interoperability and portability.

3.3.1 Interoperability

Currently, research has shown that EMR systems used by Saudi Arabian hospitals lack the ability to share or exchange information [5]. Therefore, the main goal of this research is to design and implement an EMR system that is able to inter-operate with others as a main and standard system. Moreover, the system will make use of data and information transparently between patients, physicians, and healthcare providers.

3.3.2 Portability

Once the system is implemented, the focus of the future is to make the system portable in different devices. Thus, the Saudi government will enable this system be integrated in portable devices and be accessed in every level possible. The idea is to achieve what other advanced countries have done, such as BYOD. Also, mobile technologies will be able to use and access data. Table 1 provides a comparison of the existing EMR systems, including our proposed EMR system for the Saudi Arabian government.

Table 3.1 Comparison of EMR systems

EMR system and Hospital / CHARACTERISTICS	Cerner EHR (KFSH&RC)	QuartaMed EMR (KAMC)	TrackCare EMR (KKESH)	Cortex EMR (KFMC)	Intersystem EMR (SAHC)	Our EMR system Approach
System Operational characteristics						
Correctness	Yes Stage 7 on EMRAM	NO Customers were not involved	NO Customers were not involved	NO Customers were not involved	No Customers were not involved	Yes Customers involved
Usability	NO Not user friendly	NO Not user friendly	NO Not user friendly	NO Not user friendly	No Not user friendly	Yes User friendly interface
Reliability	N/A	N/A	N/A	N/A	N/A	Yes
Efficiency	Yes	Yes	Yes	Yes	Yes	Yes
Security	NO No connection out of the organization	NO No connection out of the organization	NO No connection out of the organization	NO No connection out of the organization	NO No connection out of the organization	Yes Secured by MOI/MOH
Safety	N/A	N/A	N/A	N/A	N/A	Yes
System Revision Characteristics						
Maintainability	N/A	N/A	N/A	N/A	N/A	Yes
Flexibility	NO Change in software not acceptable	NO Change in software not acceptable	NO Change in software not acceptable	NO Change in software not acceptable	NO Change in software not acceptable	Yes Change at anytime
Scalability	N/A	N/A	N/A	N/A	N/A	Yes Easy to upgrade
Testability	N/A	N/A	N/A	N/A	N/A	Yes
Modularity	N/A	N/A	N/A	N/A	N/A	Yes
System Transition Characteristics						
Interoperability	NO	NO	NO	NO	NO	Yes
Reusability	NO	NO	NO	NO	NO	Yes
Portability	NO	NO	NO	NO	NO	Yes

CHAPTER 4: RELATED WORK

The approaches of using EMR systems are not the same in all countries. There are those that use a centralized system, while others use individual systems. In the United States, many providers use the centralized system and the government went ahead to institute laws where they punish medical providers who did not adapt EMR. Denmark has a centralized electronic database of its citizens' medical records going back as far as 1977 for basic records and back as far as 2000 for detailed histories. Approximately 98% of primary care physicians have access to the system, including all hospital physicians and pharmacists. In 2013, the Ministry of Health in United Arab Emirates worked with Nuance Communications Inc. to enable the EMR systems to function effectively. Moreover, in recent times they enable the patient to have access to their record [18].

Past research indicates that EMR systems in Saudi Arabia are used individually in healthcare facilities by the healthcare providers. The systems are only used in individual health centers and have not been integrated with other healthcare centers, thus making it difficult for different health centers to share information amongst them [5]. Therefore, having an integrated system that enables linkage between the healthcare providers within the entire country will be more than valuable, as it will make it easy to access patient information from any healthcare facility by any healthcare provider.

4.1 Identification of the Existing Approaches

The utilization of information technology to deliver and improve healthcare services is to enhance the quality of health services, reduce medical errors, and improve patient care. Use of EMR systems started in early 1977 [18]. Early EMR adoption led to design and implementation of various models of health information exchange (HIE). Different models could be adopted and implemented by one country across their regions or even in one same region. However, there are some countries that have implemented a standard model to unify and facilitate the exchange of EMR. Basically, three models for exchanging electronic health record (HIE) have been developed and implemented which have led in turn to advancing systems with new and recent information technologies, such as cloud technology.

The models of exchanging EMR are categorized into three different functions models based on HIMSS: Centralized model, Decentralized or Federated model, and Hybrid model. The three models describe and carry the best solution practices of exchanging EMR between healthcare providers and also to enable patients' access to their personal records [19]. This thesis has an interesting scope as it focuses on adopting standard EMR systems in Saudi Arabia. Recent statistics shows that 11 out of 22 hospitals in Riyadh city, either nonprofit Governmental, or profit (private) hospitals, have already established a fully functioning EHR system, while eight others are in the process of implementation [20]. The exchanging of EMR between these hospitals and healthcare providers has not been established. Furthermore, the patient does not have any access to their medical record. Based on that, the exchanging approaches have not been

implemented, which is contrast to what is happening in other countries.

4.2 Descriptions of Each Solution

Based on the differentiation in perspective of adapting EMR in different countries, exchanging health information (EHI) has different models and architectures. In general, Centralized, Federated, and Hybrid models are the most commonly used. Indeed, some countries have all three models implemented and the reason behind it is that they adopted EMR a long time ago. The early adoption has constantly caused incompatibility issues in these countries due to lack of a similar platform for exchanging information.

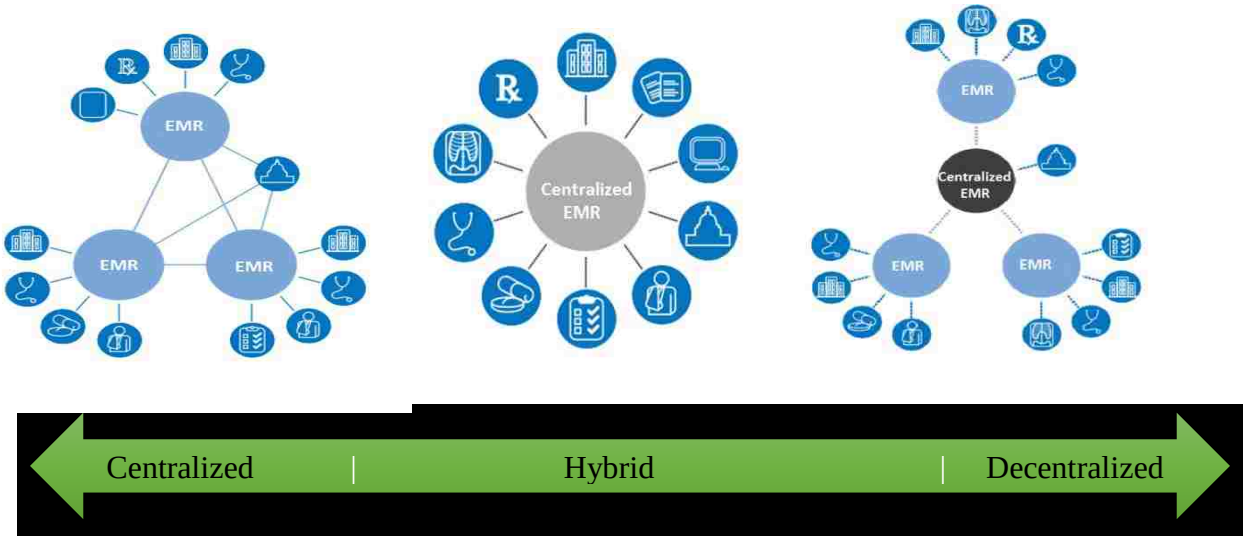
In the centralized model, the patient data or record are transferred and collected from providers such as hospitals, clinics and stored in central repository. The architecture design of this model depends basically on a large database system that aggregates similar data from numerous sources in one location. Having all data in one location makes queries for retrieving this data easy and fast, increasing the performance of the system.

The Decentralized or Federated Model provides organizational control of the healthcare record and provides the framework for data sharing capability to enterprises, perhaps widely distributed across regions or even nationally. The local entity owns their data and the Record Locator Services manages the pointers to the information.

The Hybrid Model is a combination of both centralized and decentralized architecture. A Hybrid Model provides the interface engine for which organizational

entities in the HIE communicate. In hybrid architecture, only some of the actual data is replicated to the central data repository. The hybrid model may also include elements where data is produced locally and the original is stored centrally, but the centralized repository and locator registry are dependent on federated EHR adapters for production of links to the original patient information. In addition to the required data to identify the patient, the central database may store a minimum of clinical data. This is commonly referred to as a “minimum clinical data set” and may include such information as current medications, current diagnoses, and allergies. In addition to these few elements, there are also pointers to where additional data is housed. Figure 4.1 shows the three different models.

Figure 4.1 The three health information exchange models



All three models offer solutions for exchanging healthcare information that are possible to implement in the Saudi Arabia environment. However, the best solution is adapting the centralized data model by the Ministry of Health (MOH) as cloud-based

system to reduce the efforts and also save cost and time.

4.3 Problems of the Existing Approaches

Each model has its advantages and disadvantages. Here we discuss possible problems.

4.3.1 Problems from the Federated Approach

A decentralized approach to EMR is primarily used in some hospitals. However, the hospitals that have applied the use of this kind of model experience common challenges relating to the approach. The extent to which the health practitioners can give their services is limited because they are not guaranteed access to the availability of files and data control. This means that when there are some end users working together in a common case, the absence of the individual who is responsible for maintaining the files would mean that the rest of the team would be stranded till the person comes back [21]. Moreover, this approach will make the patients' file to be insecure. When confidential files are insecure, they may be accessed by unauthorized personnel, which may lead to the hospitals being sued by patients. On the same, such occurrences will mean that the hospitals will be violating the Health Insurance Portability and Accountability [22]. Hospitals using Federated Model are still struggling in defining their profile and standards.

4.3.2 Problems from the Centralized Approach

As much as the Centralized Approach to EMR has been credited with some positive reasons, it also has some demerits. A Centralized Approach for adapting EMR requires strong central coordination, since the central database cluster needs to be carefully managed and maintained for this system to work. Also, the privacy and security aspect will require more effort and protections according to the single point of failure. Furthermore, it also requires a large effort to keep not only demographic records but also clinical records free from duplication, since these records will be collected from numerous disparate sources.

4.3.3 Problems from the Hybrid Approach

Using the Hybrid Approach, not all the actual data are simulated to the central data depository. This may lead to a lot of inconveniences in the data that have not been replicated. In this model, the original data may be first obtained in one of the departments, but will be stored by the top management of the hospital. This means that data is produced locally though it is stored centrally. However, both the locator registry and the centralized repository depend on the decentralized approach for obtaining links of the initial patient in the central formation [23]. The approach highly depends on the central database to store its information. However, the central database may lack the capacity to store all the clinical records. This is disadvantageous to the hospital. This approach also poses a threat of database congruency to the hospitals. Data congruency is where the messaging format,

methods for obtaining data and field naming convention used by the hospital are not constant. Table 4.1 compares each approach with advantages and disadvantages of each.

Table 4.1 Comparison of approaches

Centralized Approach	Federated Approach	Hybrid Approach
Strong central coordination is required since the central database cluster needs to be carefully managed and maintained for this system to work.	Need to ensure authorized and legitimate access to third party systems connected.	Replication of data since sometimes not all the actual data are simulated to the central data depository
Dependence on large central database for inter-system queries	Need to capture consumer consent to opt in and opt out of the decentralized network thus ensuring legitimacy for data usage.	Overreliance on the central database to store its information. However, the central database may lack the capacity to store all the clinical records.
Data timeliness issue: data submission from participating systems to central database may lag resulting in inaccurate consolidated records at query time.	Standards and profiles are still being defined	Poses a threat of database congruency to the hospitals
Likely fairly expensive option to implement, not only technically but organizationally.	Data control and availability is not guaranteed thereby limiting the value that can be achieved by the providers.	--

CHAPTER 5: PROPOSED SOLUTION

5.1 Overview

The evolution of Health Information Systems started a long time ago to enhance healthcare services, increase healthcare productivity, and unify healthcare researcher's efforts. Each country has worked continuously to promote and enhance their healthcare sector by adapting the recent and highly qualified systems and technology. The success, efficiency, and quality in healthcare today for countries and healthcare providers are measured through the systems and technologies that have been used to provide healthcare services. One of these systems that give a competitive edge of some countries over others in Health Care information technology is adapting EHR system and the potentiality for exchange and sharing of these records between different healthcare providers. Many nonprofit global organizations have been founded to improve healthcare quality, efficiency, access and adapting of EMR through using IT and management systems. For instance, Healthcare Information and Management Systems Society (HIMSS) is a global organization focused on leading healthcare providers to optimize provided services using IT [24].

HIMSS analytics created a model called the Electronic Medical Record Adoption Model (EMRAM) to allow a specific healthcare organization to measure and score their progress in adapting EMR over and against other organizations, either inside their own country or out of it [25]. The model includes 8 stages with different cumulative capabilities as shown in Figure 5.1.

EMR Adoption Model SM	
Stage	**Cumulative Capabilities**
Stage 7	Complete EMR integrates all clinical areas (e.g. ICU, ED, Outpatient) displacing all (medical) paper records in the hospital; Continuity of Care standards to exchange data; Data Warehouse used as basis for clinical and business analytics
Stage 6	Clinical Documentation interacts with advanced Decision Support (based on discrete data elements) AND Closed Loop Medication Administration
Stage 5	Integrated Image Management Solution (e.g. PACS) displaces all film-based images throughout the hospital
Stage 4	Electronic Ordering provides Clinical Decision Support (based on rules engines) in at least one clinical service area and for medication
Stage 3	Clinical Documentation as well as Electronic Ordering of Physician and/or Nursing Care services; includes tracking of Medication Administration (eMAR)
Stage 2	Clinical Data Repository / Electronic Patient Record allows collection and normalization of data from disparate clinical sources throughout the hospital
Stage 1	Information Systems for major ancillary departments (Laboratory, Radiology, Pharmacy) are installed or data output from external service providers are processed electronically
Stage 0	Information Systems for major ancillary departments (Laboratory, Radiology, Pharmacy) are not installed or data output from external service providers cannot be processed electronically

Figure 5.1 HIMSS - 8 stages of EMR adoption (http:www.himssanalyticsasia.org/emradoptionmodel.asp)

Advanced countries have used this model to measure and compare their progress in adapting and exchanging EMR. HIMSS also provides an updated database about the current situation and comparison tables of EMR in specific countries. Figure 5.2 below shows a recent statistic of the stages that the U.S and Canada have reached.

United States EMR Adoption Model℠

STAGE	2015 Q3	2015 Q4
Stage 7	4.1%	4.2%
Stage 6	25.4%	27.1%
Stage 5	34.6%	35.9%
Stage 4	10.3%	10.1%
Stage 3	17.3%	16.4%
Stage 2	3.4%	2.6%
Stage 1	1.8%	1.7%
Stage 0	3.1%	2.1%
	N = 5464	N = 5454

Canada EMR Adoption Model℠

STAGE	2015 Q3	2015 Q4
Stage 7	0.2%	0.2%
Stage 6	0.9%	0.9%
Stage 5	3.1%	3.4%
Stage 4	1.7%	1.6%
Stage 3	31.3%	31.2%
Stage 2	31.3%	31.5%
Stage 1	14.1%	13.9%
Stage 0	17.5%	17.3%
	N = 640	N = 641

Figure 5.2 HIMSS EMRAM of U.S.and Canada (http://www.himssanalytics.org/provider-solutions)

Using EMRAM to measure the current progress of adapting EMR in healthcare organizations in Saudi Arabia as a scope of this research work will lead to better understanding of the current situation of EMR. Based on the recent statistics from HIMSS conference, there are only two hospitals in Saudi Arabia that have achieved stages 6-7 [26]. By studying these two hospital systems and getting the standard functional and non-functional requirements of sharing and implementing for all healthcare providers in Saudi Arabia with cloud-based EMR technology will lead the country to advance stages in HIMSSS compared with other countries.

Essentially, prior to implementation of an EMR system, most developers are always intrigued by two primary questions: *How can we build a national EMR system that is capable of serving an entire nation?* and *What are the specific functions that the system will perform?* To answer these questions, the following section is aimed at describing the requirements that should be considered during design phases. Furthermore, guidelines to help in understanding the development process that will be used for

building the EMR system is provided.

5.2 Involve the Stakeholders in the Process of Development

This research proposes the use of an agile development process in developing the EMR system. The requirement in an agile system is that the process should be tailored in a manner that it focuses on the customer or the stakeholder requirements and descriptions. Therefore, it is essential for developers to engage all the stakeholders in the process. The advantage of this approach is that it obtains relevant knowledge from the existing EMR system. Users or developers of the system use their experiences with their current system to meet users' new expectations. So, as our scope of work that previously mentioned, Saudi Arabia as represented by MOH and MOI is interested in who are the stakeholders of EMR system, especially the hospitals that have achieved stage 6 or 7 on EMRAM (see figure 5.3).

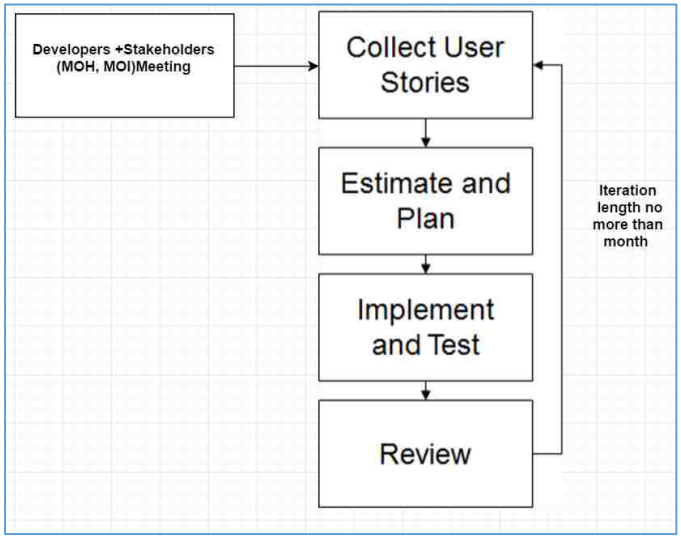


Figure 5.3 Involving stakeholders in the process of development

5.3 EMR system as standard

The complexity of implementing EMR system in the healthcare sector has evoked the need of developing a standard national system. The national system is aimed at improving the exchange and sharing of information between different systems. Various global organizations have developed standards about HIT. Some of the most important international standards that are relevant to this research are illustrated in the table below.

Table 5.1 International standards for EMR

Standard Name	Category	Description
ISO 22220	SO/TC 215 Health Informatics	Identification of subjects of health care
ISO 13606	SO/TC 215 Health Informatics	Electronic health record communication Parts 1,2,3 and 4
ISO/TR 20514	SO/TC 215 Health Informatics	Describes classification of electronic health records, provides simple definitions for the main categories of EHR and provides supporting descriptions of the characteristics of electronic health records and record systems.
ISO/TR 18307	SO/TC 215 Health Informatics	Interoperability and compatibility in messaging and communication standards — Key characteristics.
ISO/TS 18308	SO/TC 215 Health Informatics	Requirements for an electronic health record architecture
ISO 27799	SO/TC 215 Health Informatics	Information security management in health using ISO/IEC 27002
ISO/HL7 16527	Health Informatics	HL7 Personal Health Record System Functional Model, Release 1 (PHRS FM).
CCHIT Certification	Health Informatics	EMR certification criteria.

Implementing EMR system in Saudi Arabia will help to create our own customized EMR standard that works for the whole country.

5.4 Privacy and Security

When it comes to cloud services, a lot of concern revolves around privacy and security issues. This research is based on a cloud EMR system as a national system. Therefore, we need to maintain the access for EMR available and while protecting data

privacy and security. From this point, the idea of adopting the EMR system through the Saudi government has started. Mainly, three basic reasons brought us to suggest the adoption of EMR system to be by the government (MOH & MOI):

- Decision makers
- Physical Infrastructure
- Data representation

5.4.1 Decision makers

Countries that have implemented EMR systems through different healthcare providers have been struggling with exchanging EMR because of who is authorized to access and check the patient data and who is responsible to administrate the access control to these data. Thus, the privacy issue has been raised and conflict between healthcare providers about controlling the access to data has appeared. Various solutions have been proposed to solve this issue, however the results have been unsatisfactory. After we reviewed many EMR privacy challenges and some proposed solutions, the idea of adopting the EMR system via Saudi government became our optimal choice. The reasons are:

- Governments are more capable and ready to follow and implement international standards such as HIPAA, ISO, and HL7.
- The Saudi government represented by MOI already has government systems that are running now on the cloud, and all the regulations for access controls and privileges are ready and implemented [32].

- Employees at MOI are well trained to protect and secure the data more than others in the country according to the systems that currently are running and the response to attacks that happened in the past [32].

5.4.2 Physical infrastructure

Nowadays, whole Saudis government systems and even some private systems are administrated and provided via MOI, including advance hardware infrastructure (servers, hubs, switches), highly qualified data centers certified with ISO, and also highly secured places as data centers for the hardware [32]. As a consequence, the most beneficial approach is to adopt EMR system through the government represented by MOH and MOI.

5.4.3 Data representations

The most precious thing in the entire system is the data itself. Thus, the need to protect the content of data through encryption is critical. Naming the database, tables, and columns should not indicate or hint to the real meaning. Also, statistical patient data should be stored in different databases. Furthermore, the access to the raw data for editing should be limited to authorized employees. Figure 5.4 outlines the process.

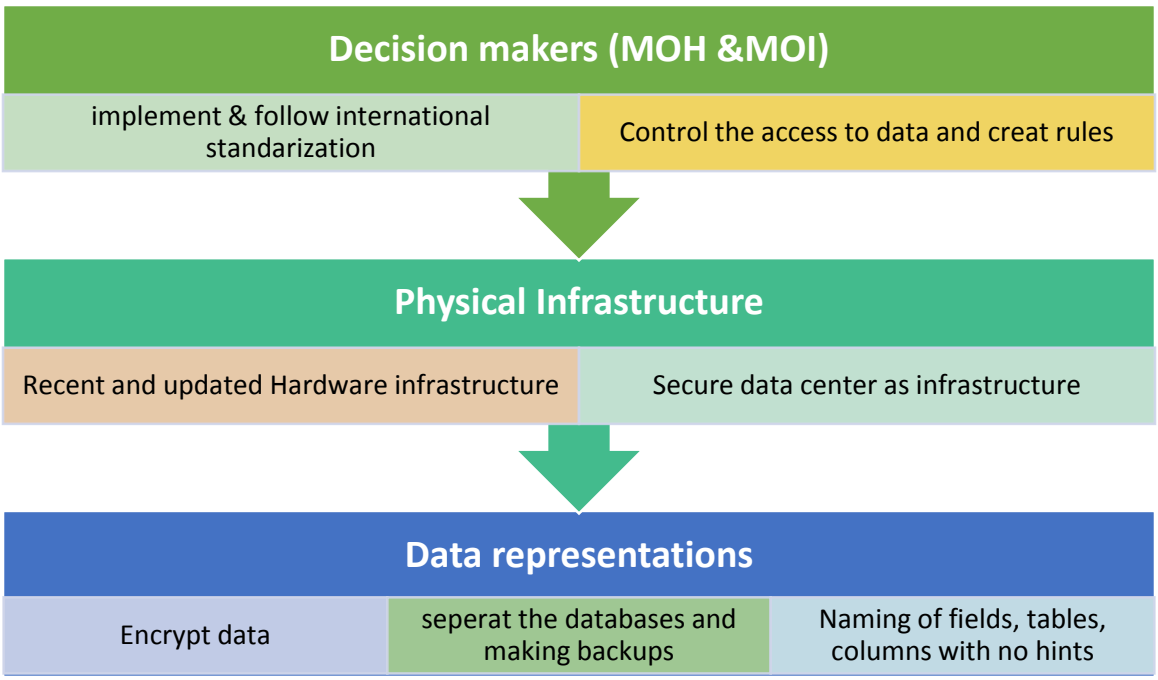


Figure 5.4 Data representations

5.5 Proposed Solution Scenarios

This research proposes the adoption of standardized EMR systems on cloud-based technology for all Saudi Arabian healthcare organizations, both private and public health centers. The implementation of the proposed solution in this research would be through MOH with the help of MOI. Centralized databases with web services will be provided to enable patients, physicians, and all the other stakeholders who use the EMR system to be able to interact with EMR systems everywhere and anytime. During the adoption of the proposed solution, three different scenarios are most likely to be experienced.

6.5.1 Scenario 1**:** Paper-based medical record

There is no accurate statistics that show the numbers of hospitals or healthcare providers that still use paper-based systems for their patients in Saudi Arabia. However, one recent study conducted on the adapting of EHR system on 22 hospitals in Riyadh city showed that three hospitals out of 22 still have not adopted any EMR system [27]. Therefore, the coordination and cooperation between MOH and the healthcare providers that still use paper-based forms should start by letting them provide preliminary patient information and the names of responsible people who interact with this information or data. Two suggested methods are:

- Design and use a customized excel sheet that meets the proposed centric database characteristics in this research (EHR system database), then send it to the concerned healthcare provider to fill it out with appropriate data and send it back to MOH to import it to the EHR database. Figure 5.5 shows more details:

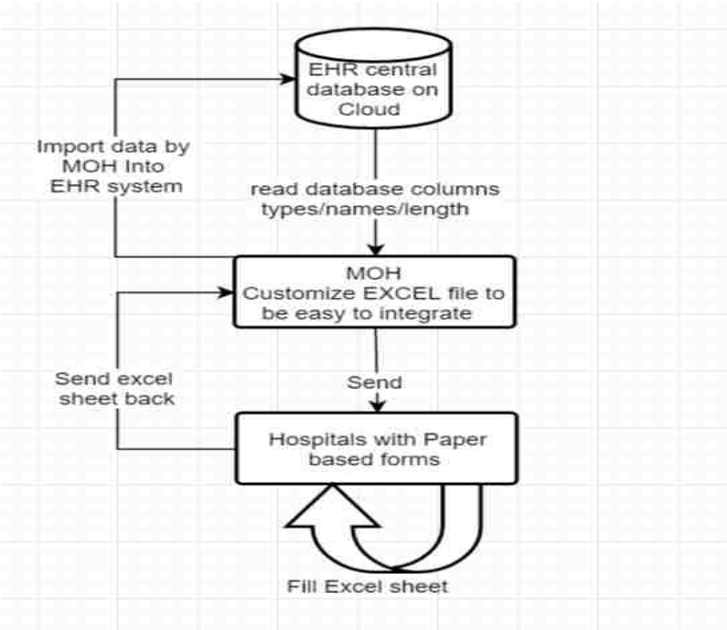


Figure 5.5 Process of transferring paper based forms into EHR

- Insert whole paper form information of the patients via API of the proposed EHR system after launching it on the cloud. See figure 5.6.

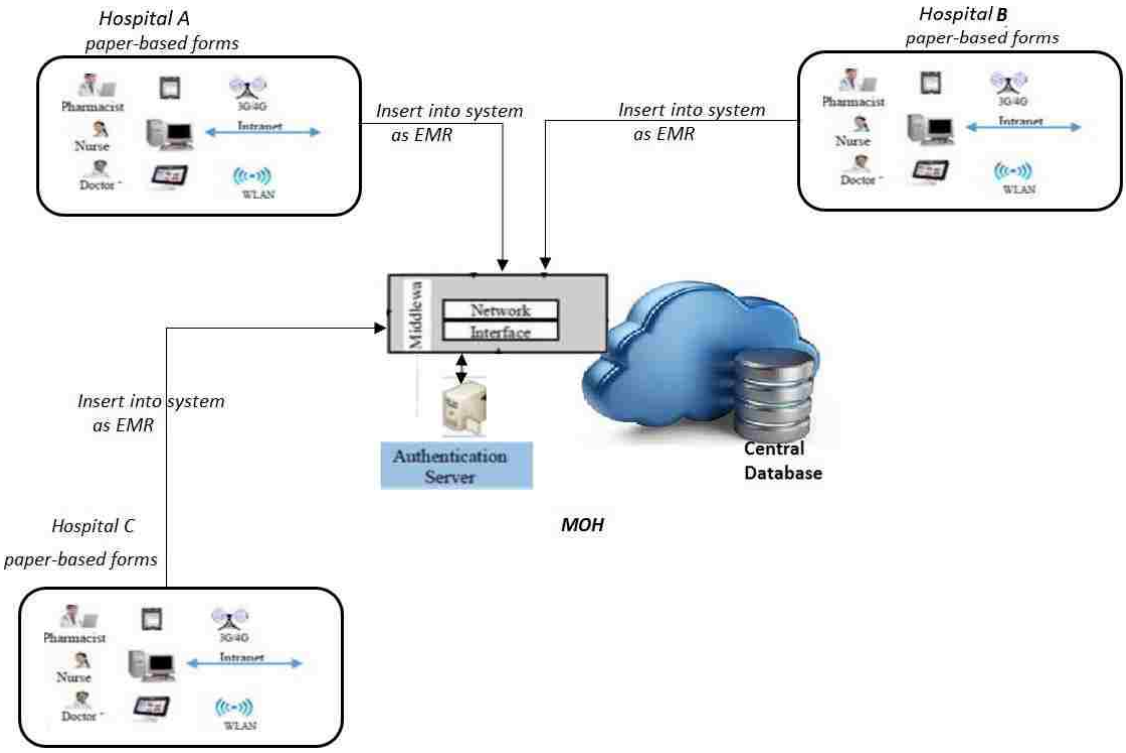


Figure 5.6: Process of transferring paper based forms into EHR system via API.

5.5.2 Scenario 2: EMR system already adopted

The adoption of EHR system in some hospitals in Saudi Arabia has already taken place or is currently underway to implementation. Some hospitals have a fully functioning EHR system, while others are still in the process of implementing it [27]. Different healthcare facilities are embracing the system. Different systems are used.

Table 5.2 Sample of survey done by Bakheet Aldosari, in 2014 on 22 hospitals in Riyadh city for adapting EMR systems

Table 1 – Characteristics of surveyed hospitals.

Hospital name	Number of respondents surveyed	Number of beds	Main specialty	Target patients	Type of EHR/EHR components
A. Nonprofit Hospitals in Riyadh					
Ministry of Health (public) Hospitals In Riyadh City					
1. King Fahad Medical City	21	1200	Tertiary	Public	Kortex EMR
2. King Saud Medical City	27	1500	General	Public	Medisys
3. Prince Salamn Bin Abdulaziz Hospital	12	300	General	Public	Medica plus
4. Alyamamah Hospital	9	360	Maternity and children	Public	Medica plus
5. Aleman General Hospital	6	300	General	Public	Oasis
6. Al-Amal Psychiatry Hospital	11	500	Psychiatry	Public	Oasis
7. King Saud Chest diseases Hospital	6	150	Chest	Public	None (Paper)
8. Rehabilitation Hospital	7	270	Rehabilitation	Public	None (Paper)
Other Nonprofit Governmental Organizations' Hospitals In Riyadh City					
9. King Faisal Specialist Hospital and Research Centre	30	936	Tertiary care centre and Research centre	Eligible patients only	Cerner EMR
10. Prince Sultan bin Abdul-Aziz Humanitarian City	12	400	Medical Rehabilitation	Eligible patients only	Intersystem (HBO) EMR
11. King Abdul-Aziz Medical City, National Guard Health Affair	36	1250	Tertiary	Eligible patients only	QuartaMed EMR
12. Riyadh armed forces hospital	25	1300	General	Eligible patients only	In-house Patient Management system
13. King Khalid Eye Specialist Hospital	13	228	Tertiary care ophthalmic facility	Eligible patients only	None (Paper)
14. King Khalid University Hospital	9	800	Tertiary	Eligible patients only	McDonnell Douglas + In-house Patient Management system
15. King Abdulaziz University Hospital	6	110	Tertiary, ENT, Ophthalmology	Eligible patients only	McDonnell Douglas + In-house Patient Management system
16. Security Forces Hospital	7	508	General	Eligible patients only	Intersystem (HBO)
B. For-profit (private) hospitals in Riyadh.					
17. Al Hammady Hospital	6	300	General	Paying/Insured Public	Wipro, RFID for Nursery + In-house Patient Management system
18. Specialized Medical Center Hospital	8	400	Specialist	Paying/Insured Public	In-house Patient Management system
19. Dallah Hospital	13	220	General	Paying/Insured Public	Commercial Careware
20. Habib Medical Centres (Arryan)	4	300	General	Paying/Insured Public	Patient Management system
21. Habib Medical Centres (Olaya complex)	5	300	General	Paying/Insured Public	Patient Management system
22. Kingdom Hospital	7	100	General	Paying/Insured Public	Cerner EMR + Iris Care

In this scenario the integration and interaction of data from different systems will bring about some issues based on the incompatibility of the data and application. Coordination between hospitals and system vendors will thus be needed and agreement with MOH required. In fact, to embrace a central EMR system on cloud-based solution as

proposed in this research, coordination is required between MOH and hospitals that adapted EMR systems and vendors of these systems. The suggested solutions for these issues are:

- Send the hospital data to MOH to import it to the EMR system database on cloud after customizing it. However, the current system used by the hospitals will consider useless and the contract of systems vendor will need to be reviewed.
- Make an agreement with the EHR system vendor to integrate or develop API for their current system to make the interaction with the proposed solution more compatible.

5.5.3 Scenario 3**:** Cloud-based EHR system

Many researchers have recommended the use EHR system on cloud. However, until now no hospitals have been able to provide online or web services for EHR systems in Saudi Arabia, and all of these suggestions and recommendations were focused on the cloud as top point of view, or as distributed systems that will lead to the main issue of exchanging this record between different healthcare providers. Similarly, other hospitals are working on this. The same suggested solutions in scenario 2 could also be implemented here too.

CHAPTER 6: SOFTWARE DEVELOPMENT

Developing software from scratch requires heavily planning, collaboration between developers and customers, and easy and quick responding to change over following the plan. Various methodologies for software development are available to use when software or application start to develop. Therefore, to begin develop EHR system one of these methodologies need necessarily to adapt.

According to the need for rapid and incremental development, effective communication between different stakeholders, and involving the customers in the work to find and eliminate requirements, agile software development methodology is the most efficient way to accomplish the desired objectives of this research [28]. In agile methodology many processes could be used or follow, however, in this research the extreme programming (XP) is the one that will be followed to develop the EHR system. The main idea of this methodology is deliver the software in incremental way, which is represented as iteration [28]. Each iteration includes user stories, acceptance test, planning, implementation, and small release.

6.1 Functional Requirements

Functional requirements are conducted and derived from users or customers of the EHR system. As a developer of a system, sitting with users to get a strong understanding of what users want from the system as a service will help to determine the requirements of

the system, either functional or non-functional. With agile methodology, using XP process the functional requirements will be determined through creating a user story for each function.

6.1.1 User Story 1

Story name: System user Authentication

Task description: The system should be able to authenticate users and enable the registered user to access with the appropriate privileges and data granted to them.

Initiating event: user of system is required to register for new account to login using ID given by hospitals. The login web page to access system using username/Password is responsible for this function.

Memory context: Store password, security question answer, and mobile number.

Observable result: If successful, show the home webpage. If not, show an error message.

Related stories: view and retrieve data from system based on the privileges. (Not required for user)

Risk factor: 4 (high)

6.1.1.1 Acceptance criteria:

- The system is available to access online successfully.

- The system is able to check the entered ID and compare it with database.
- The system is able to insert values (password, mobile number) correctly.
- The system sends a temp code to the entered number for authentication successfully.
- The system logged in successfully to next page.

6.1.2 User Story 2

Story name: Patient

Task description: Each patient is able to access the system and review his data, recent and previous diagnoses, blood tests, surgeries, radiology, medical reports, and appointments.

Initiating event: After Patient login to the system, the homepage will provide different tabs for each category to check.

Memory context: In this case only retrieve and review data; nothing is required to store.

Observable result: If successful, homepage will provide and display with functionality of check Info.

Related stories: Physician story to add patient information and results. (Not required for user)

Risk factor: 4 (high)

6.1.2.1 Acceptance criteria:

- The system is available to access online successfully.
- The system able to retrieve personal patient data from database correctly.
- The system able to display returned result to patient correctly.
- The system able to transfer between different pages and tabs easily and correctly.

6.1.3 User Story 3

Story name: Physician

Task description: Each physician is able to access the system and review the current patient file. Add diagnose and tests results.

Initiating event: After physician login to system homepage will provide with screen to find the desired patient. Also, different tabs for each category to check.

Memory context: diagnoses, lab results, blood test results and appointments.

Observable result: If successful, Homepage will provide and display with functionality of check patient.

Related stories: view and retrieve data from system based on the privileges. (Not required for user)

Risk factor: 4 (high)

6.1.3.1 Acceptance criteria:

- The system is available to access online successfully.
- The system can check physician privileges to access the authorized web pages.
- The system is able to receive patient ID provided by physician.
- The system is able to retrieve patient data from database based on the entered ID correctly.
- The system is able to update and add new patient information by physician.

6.1.4 User Story 4

Story name: Diagnosis of patient

Task description: diagnosis of patient enter immediately after physician see the patient.

Initiating event: diagnosis page to add the physician report of patient cause.

Memory context: Details diagnoses report adding by physician.

Observable result: If successful, diagnosis web page will display to add the report and retrieve it in cause of checking

Related stories: Patient, and Physician story. (Not required for user)

Risk factor: 4 (high)

6.1.4.1 Acceptance criteria:

- The system is available to access online successfully.
- The system able to retrieve previous diagnosis of patient.
- The system bale to add new patient diagnosis by physician.
- The system bale to change and update on current diagnosis in cause of entered by mistake.

6.1.5 User Story 5

Story name: Laboratory services

Task description: laboratory are able to keep the patient test results and physician comment and make them available to use anytime

Initiating event: laboratory page to add the physician report of patient test results.

Memory context: Details patient test either pictures or information that added by physician.

Observable result: If successful, laboratory web page will display to add the test results and retrieve it in cause of checking.

Related stories: Patient, and Physician Diagnosis stories (Not required for user).

Risk factor: 4 (high)

6.1.5.1 Acceptance criteria:

- The system is available to access online successfully.
- The system able to keep patient test results.
- The system bale to add new patient comment on the test result by physician.

6.2 Non-functional Requirements

In software engineering, non-functional requirements care more about systematic approaches to develop software systems with the desired level of quality [29]. Based on the fact that this system will adopt cloud technology as SaaS for all healthcare providers in Saudi Arabia, the demand on non-functional requirements (NFR) to be satisfied will be crucially needed. Many NFRs are required to meet and the priorities between them be determined [30]. The following list shows the most NFRs that our system should achieve either on short or long term:

1. EMR System requirements:
    - Efficiency requirements (space and performance requirements)
    - Reliability requirements
    - Portability requirements
    - Usability requirements
    - Privacy requirements
    - Security requirements
2. Organizational requirements represented by MOH:
    - Implementation of the system
    - Standards of system
    - Delivery requirements

6.3 Test-driven Development (TDD)

Using agile development methodology to develop EHR system requires incremental or rapid development along with testing in each iteration of system deliveries. Test driven is one process to test the short delivered iteration of a system based on user stories [31]. In this research the test driven for the whole system has been collected in Table 6.1.

Table 6.1 Functional test cases

TCID	Name	Description	Priority (High-Medium - Low)	Expected Result	Execute (Yes-No)	Execution Date	Execution Status		comments
							Passed	failed	
TCID001	Access online	Verify that EHR system is available to access online.	H	The EMR as web service are available online.	-	-	-	-	
TCID002	The Login authentication	Verify that system able to check the authorized users.	H	Take decision to grant user access or not .	-	-	-	-	
TCID003	New user	Verify system is able to register new user to access	H	Form for registration.	-	-	-	-	
TCID004	Tem code	Ensure that system is able to send temp login code for verification.	H	Form to insert the code received on mobile number.	-	-	-	-	
TCID005	Patient	Verify that patient able to review his EMR data anytime and everywhere.	H	Web pages with EMR for patient.	-	-	-	-	
TCID006	Physician	Ensure that physician is able to retrieve EMRs for patient and update them if needed.	H	Web pages for the required EMR.	-	-	-	-	
TCID007	Diagnosis	Verify the system is able to upload the patients diagnosis added by physician.	H	Web pages for diagnosis to add physician's reports.	-	-	-	-	
TCID008	Laboratory services	Verify that the system is able to add and retrieve lab data or tests results for patients.	H	Web pages for lab results (pictures or reports)	-	-	-	-	

Defect No	Category	Severity	Status(open – fixed - closed)	Date reported	Reported by	Problem description	Requirement	Impact

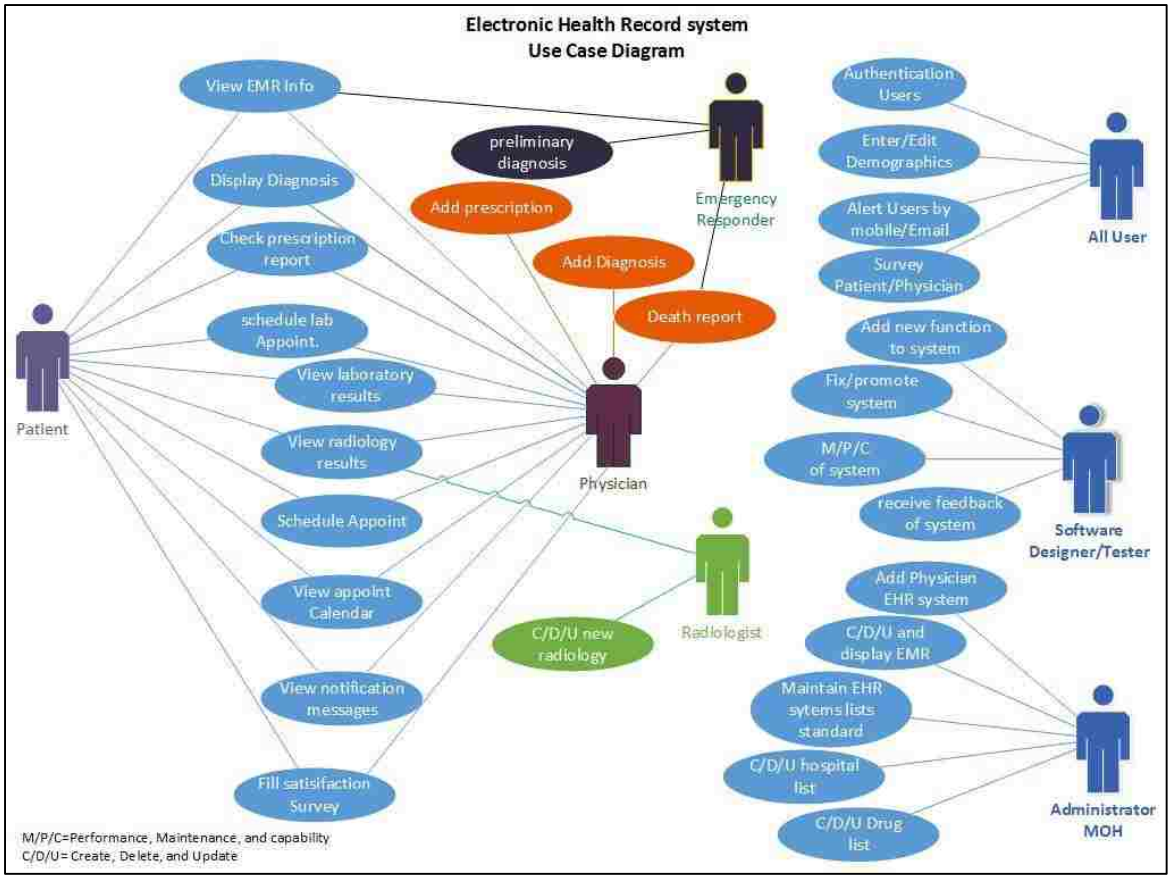
6.4 EHR System Design

The main purpose of documenting the design phase is to give a detailed roadmap of the developing process of EHR system to the developer. Many assumptions are reviewed and eliminated to make the system standards easy to interact with different functions required. Supporting this research with diagrams that agile methodology use will promote the concept and functions that EMR/EHR system depend on. Next we introduced more details about software diagrams.

6.4.1 EHR system use case diagram

Now that we have EMR system requirements, building the use case diagrams will facilitate the understanding of the interactions between system users (actors) and functions that the system performs (see figure 6.1). Note that, in order to make our system more efficient, eight actors were included and 28 functions or events were added. The roles that user' plays are different based on their authority, tasks that they are responsibilities for, and their positions either in healthcare hospitals or MOH/MOI. For instance, physician is able to add and display patient information, diagnosis, and laboratory results based on his/ her responsibility but not able to add or delete him/her from system because of authority.

Figure 6.1 Use Case Diagram of EHR System



6.4.2 EHR system sequence diagrams

The sequence diagrams will show how our system objects interact with each other and also provide the order of the actions or events that users interact with. Four main sequence diagrams are added to improve the understanding of our system.

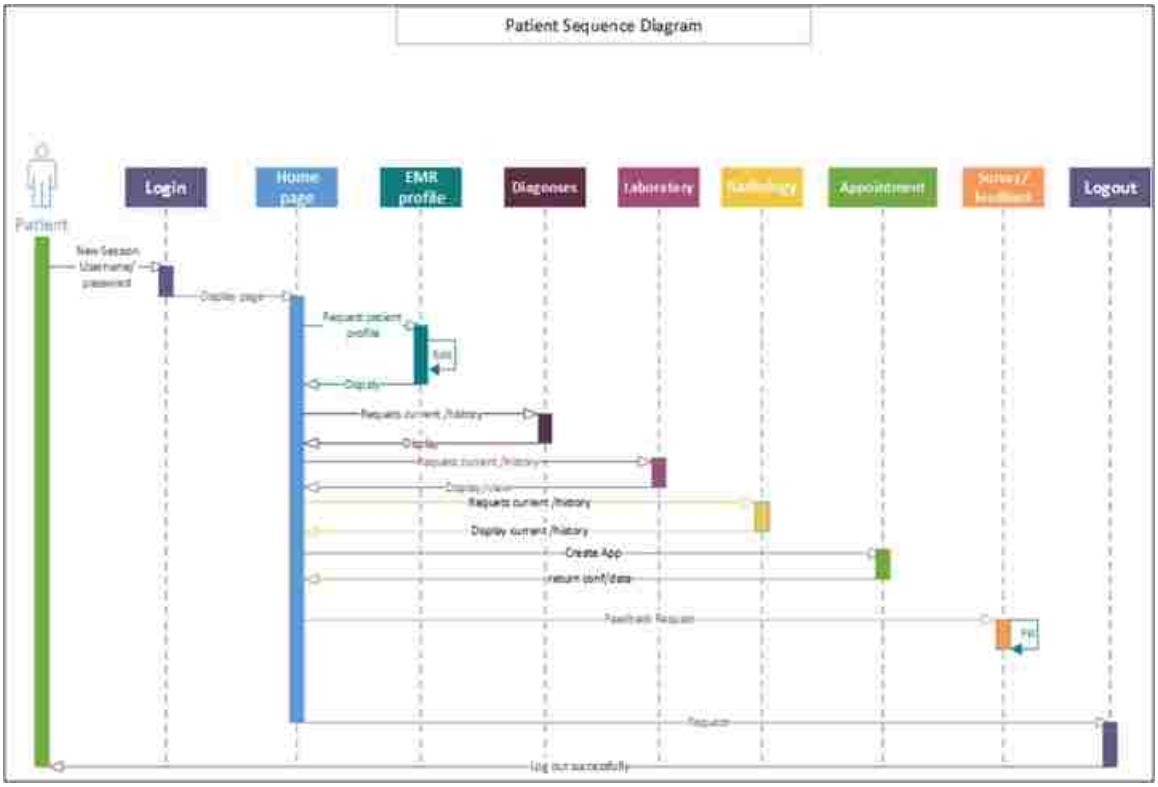


Figure 6.2 Sequence diagram for the patient of EHR system.

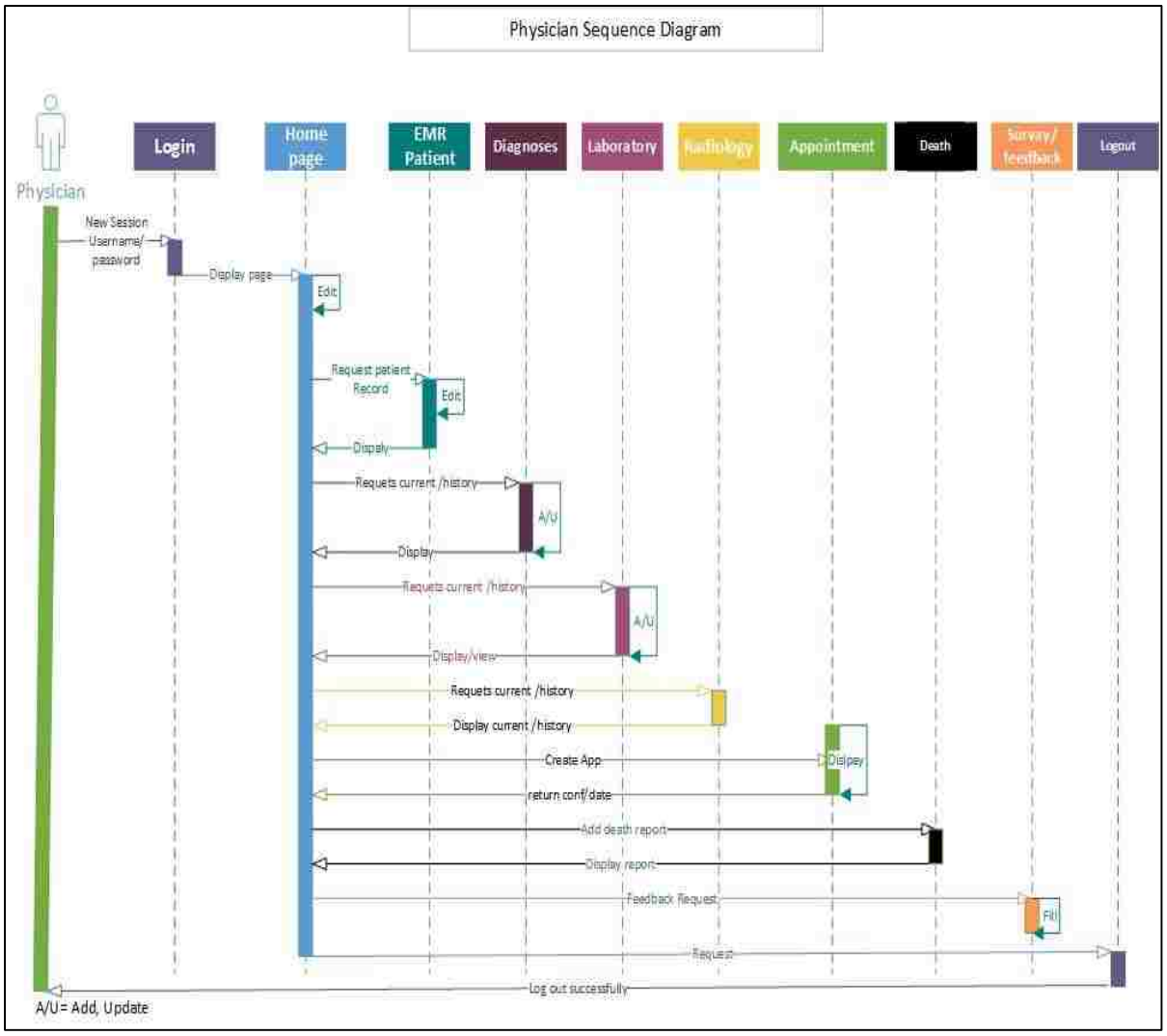


Figure 6.3 Sequence diagram for the physician of EHR system

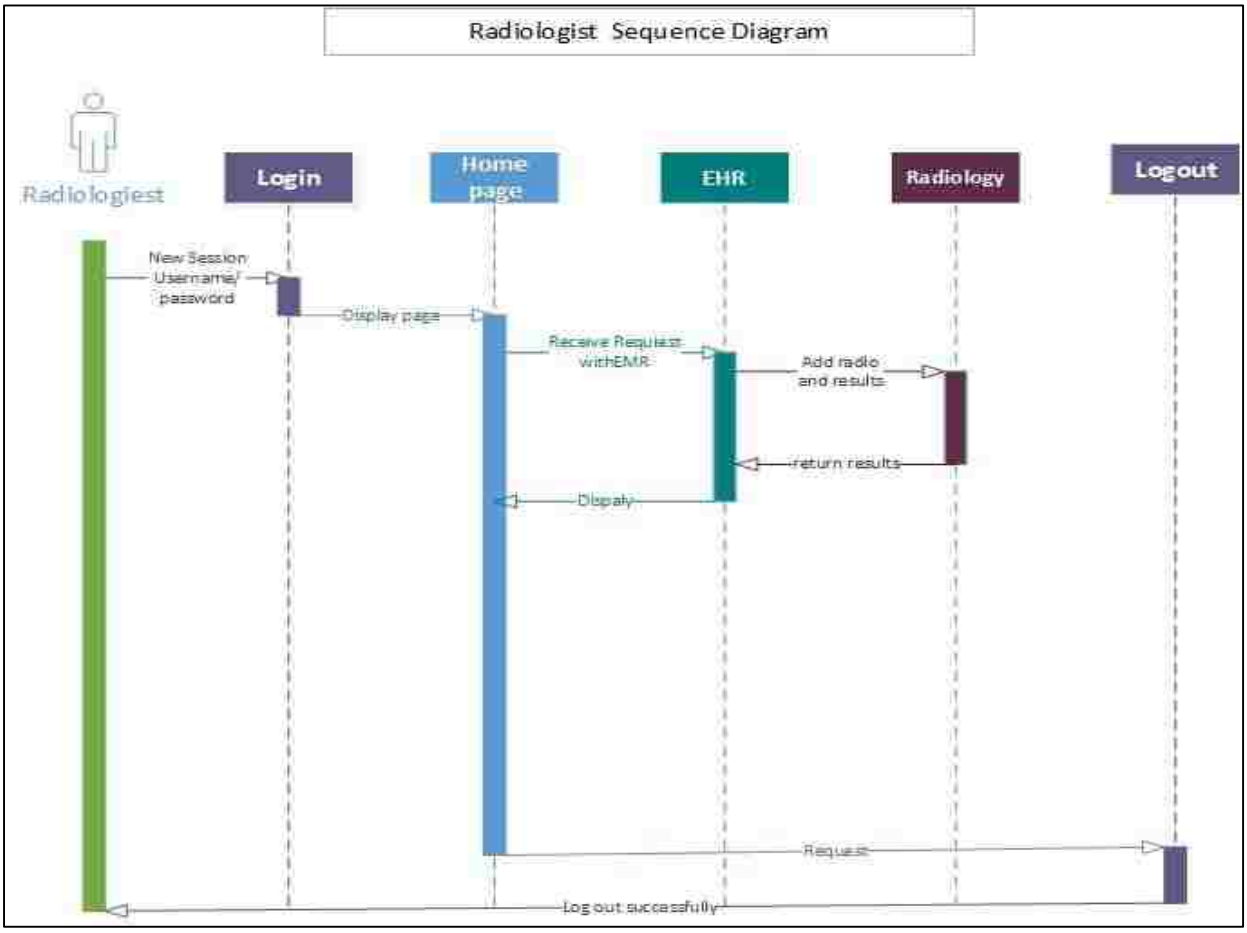


Figure 6.4 Sequence diagram for the radiologist of EHR system

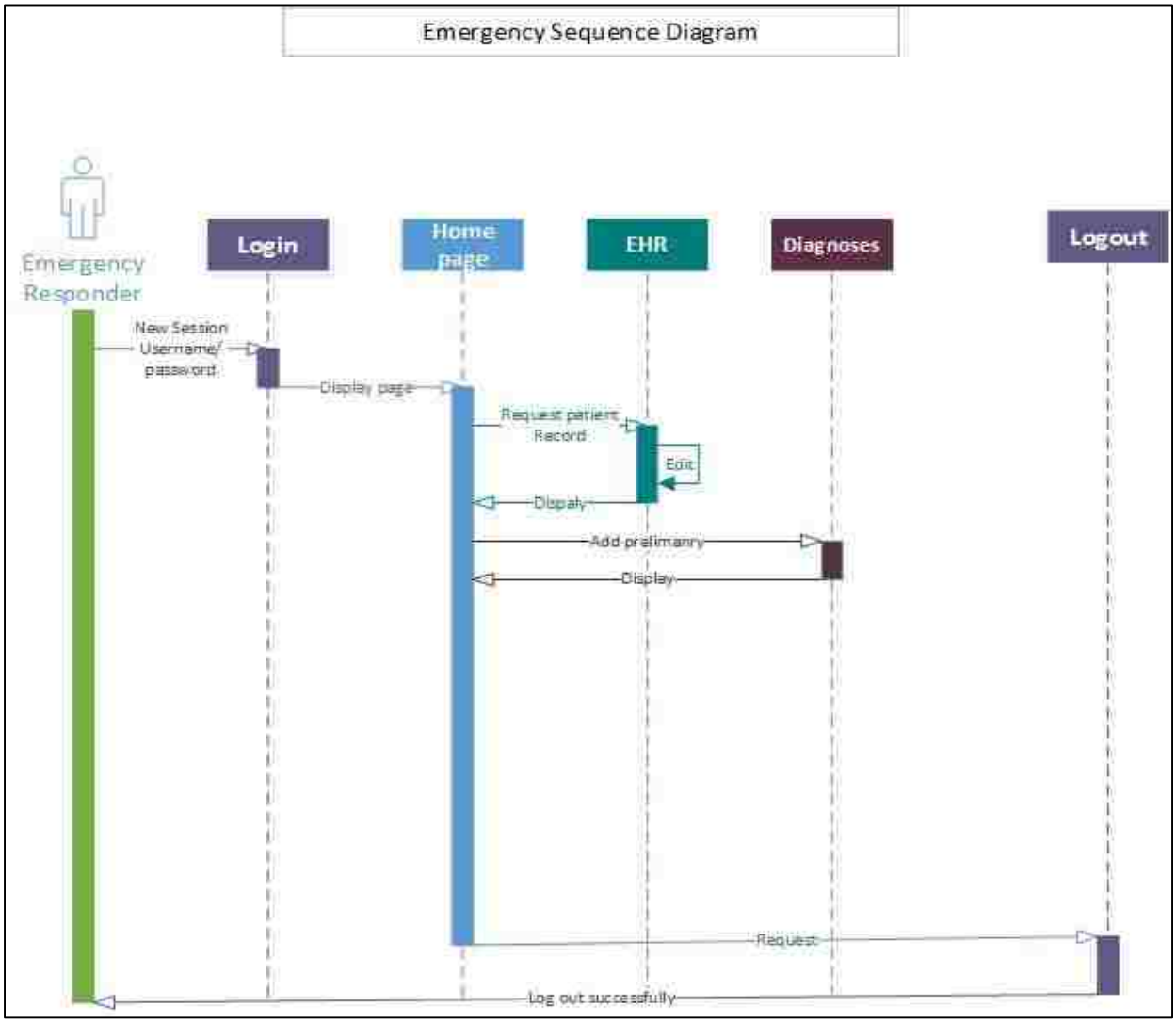


Figure 6.5 Sequence diagram for emergency service of EHR system

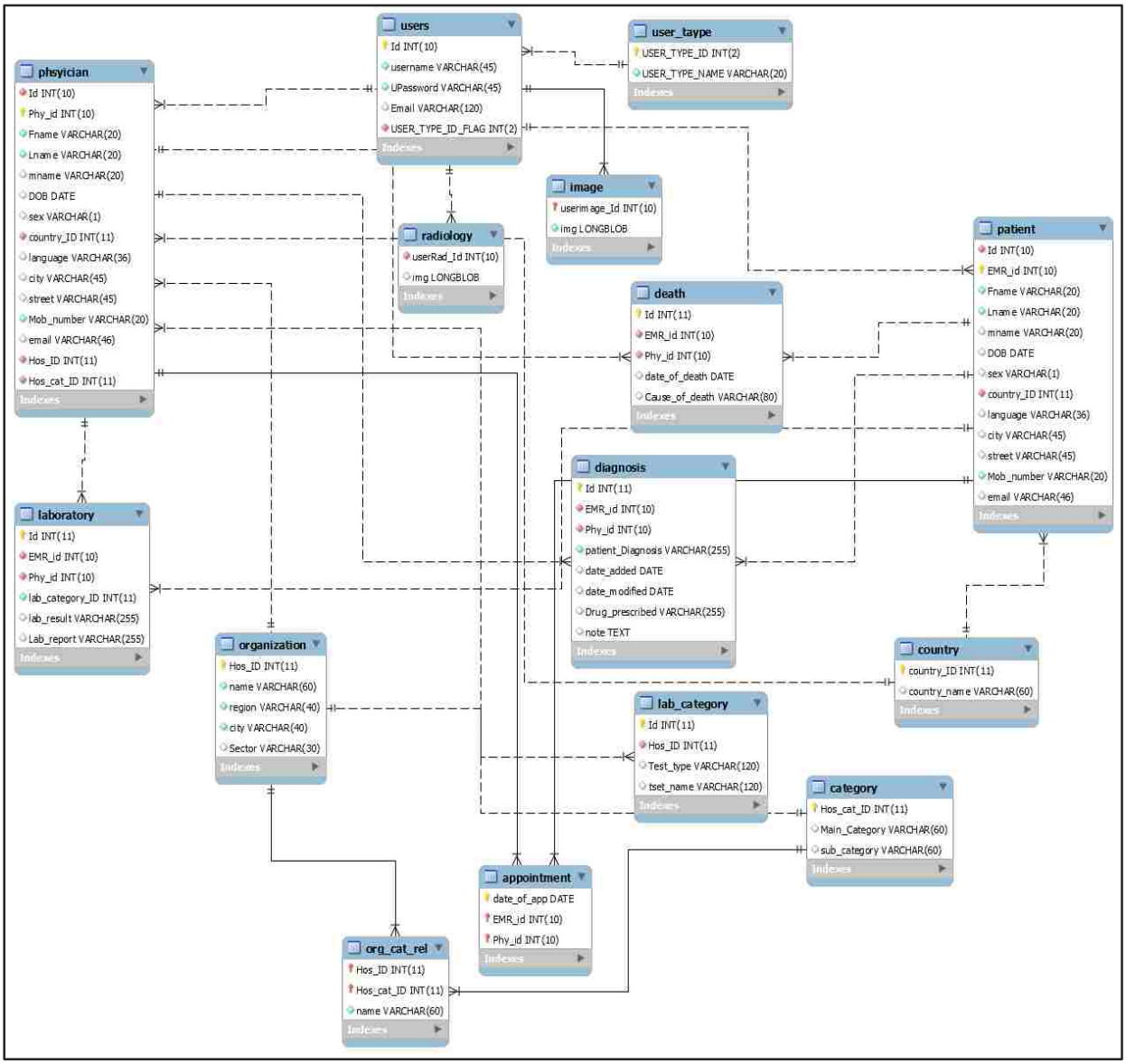


Figure 6.6 EER diagram of EHR system

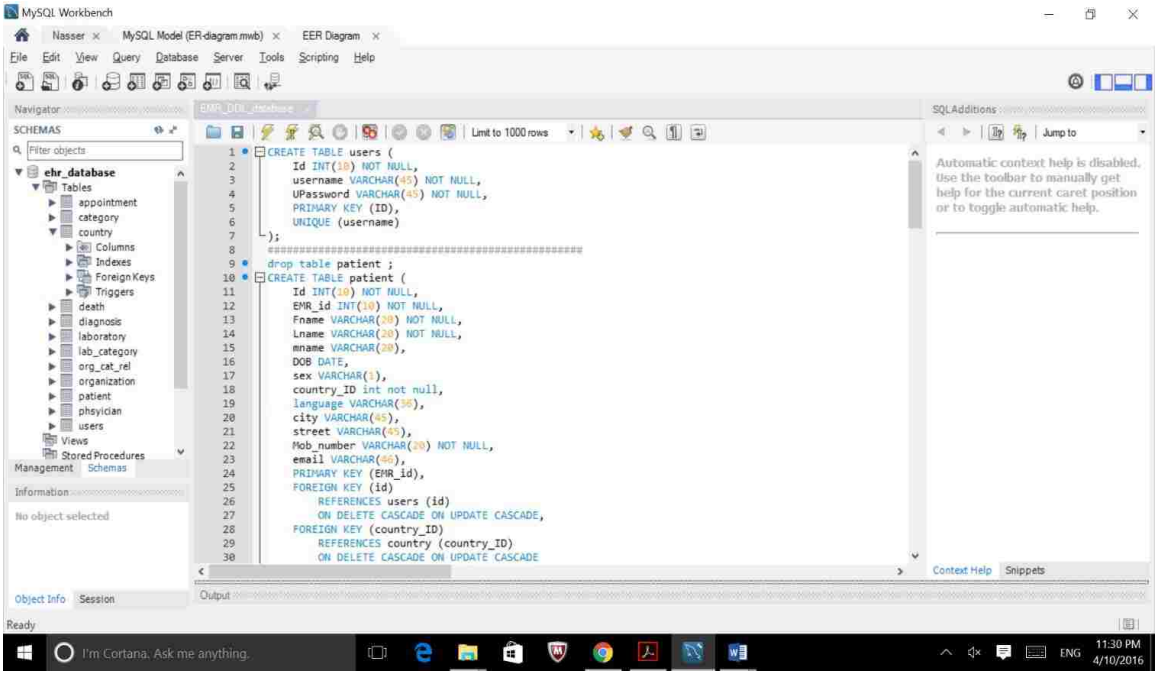


Figure 6.7 DDL of users and patient tables of EHR system

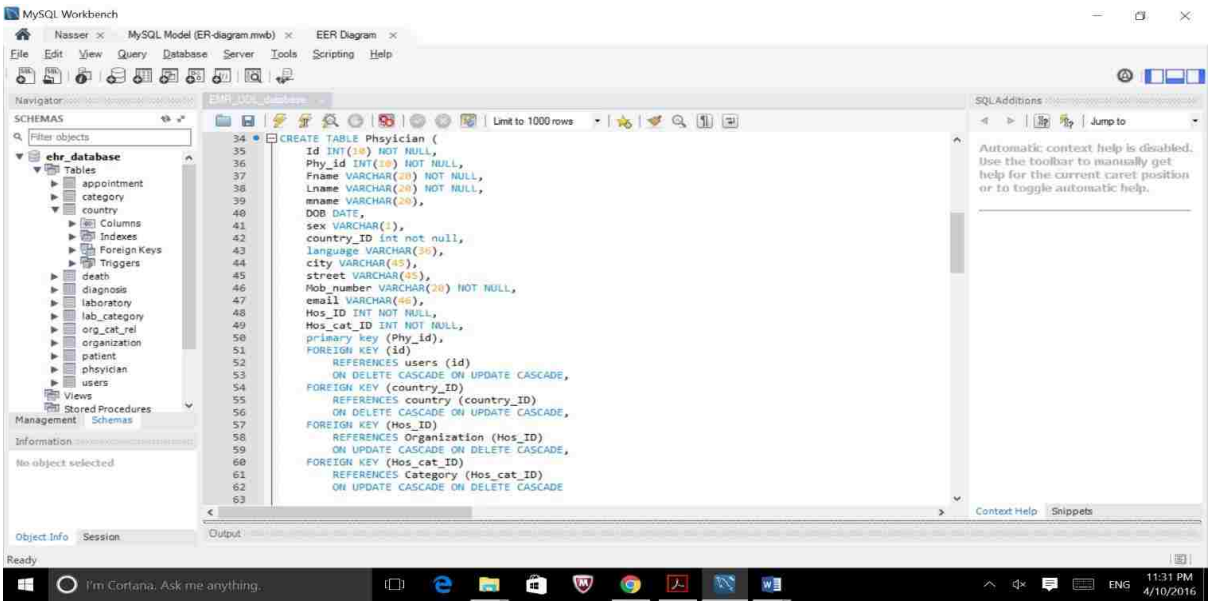


Figure 6.8 DDL of physician table of EHR system

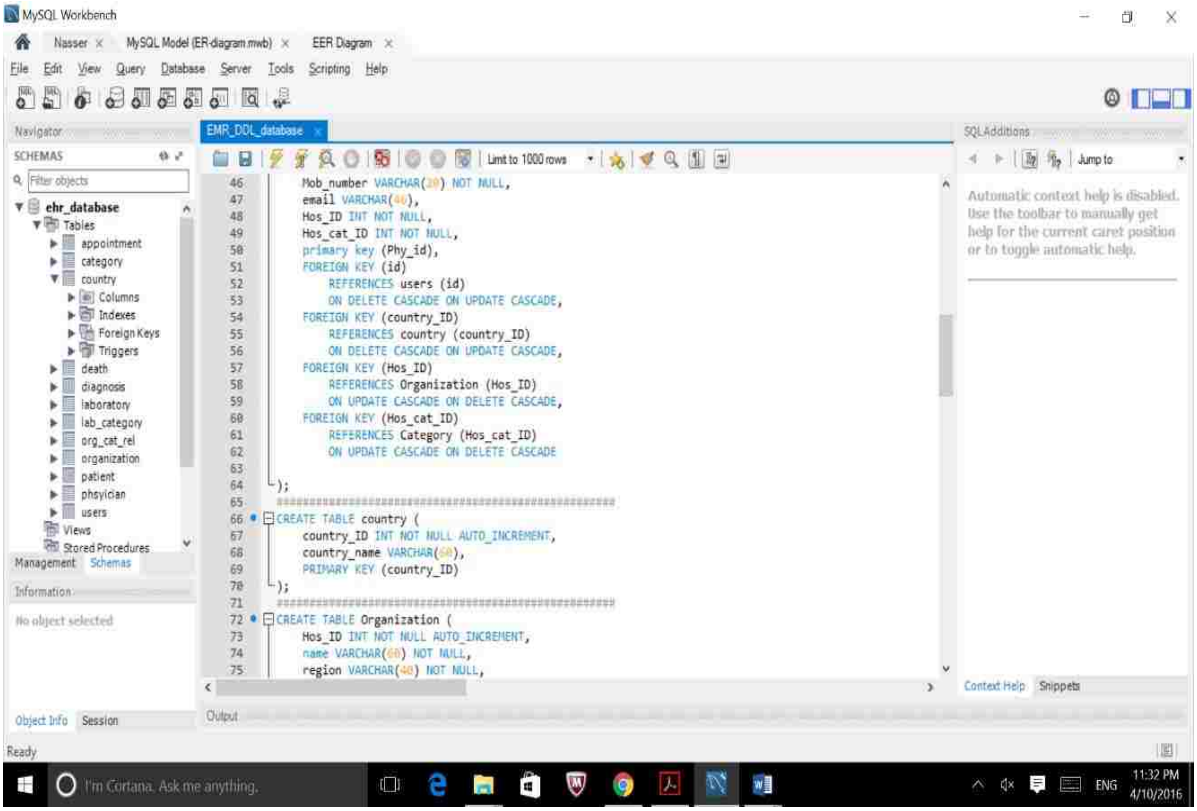


Figure 6.9 DDL of country a look up table of EHR system

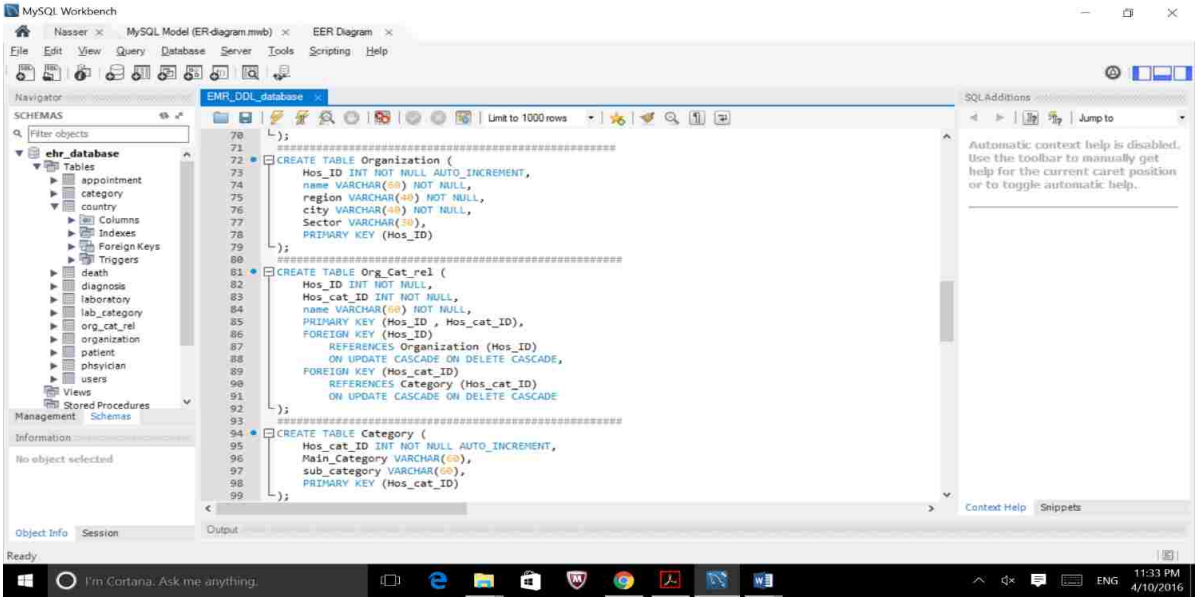


Figure 6.10 DDL of organization and category tables of EHR system

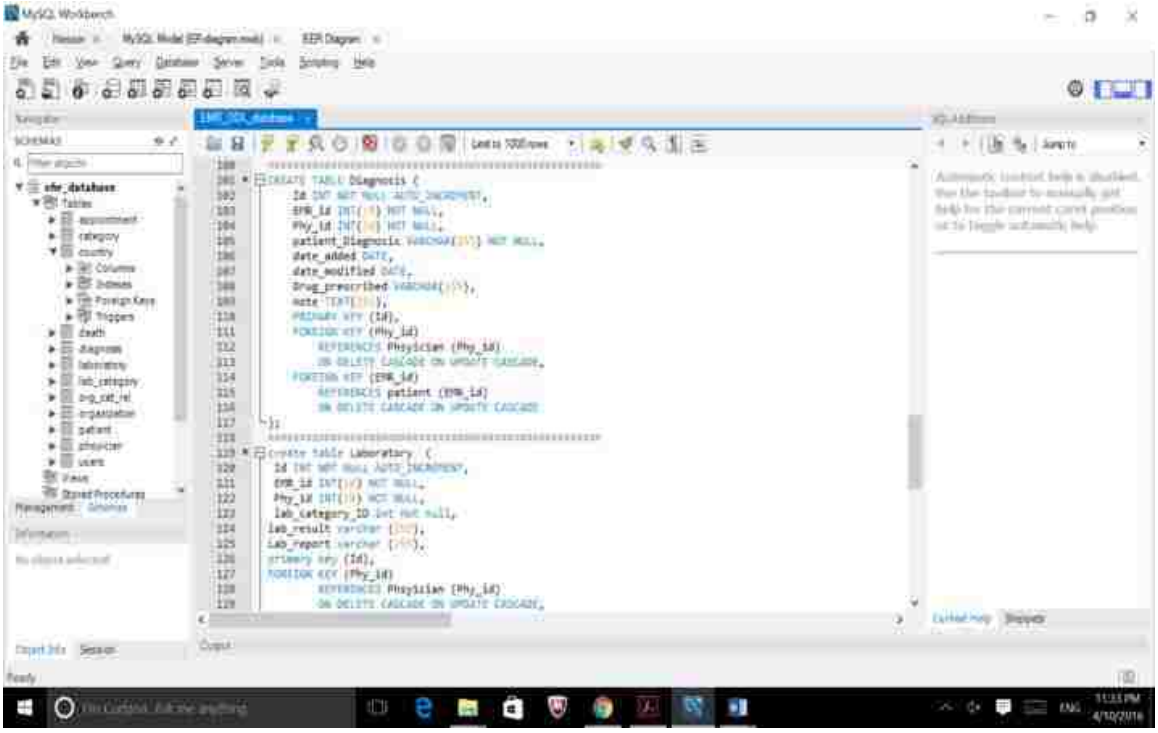


Figure 6.11 DDL of diagnosis and laboratory tables of EHR system

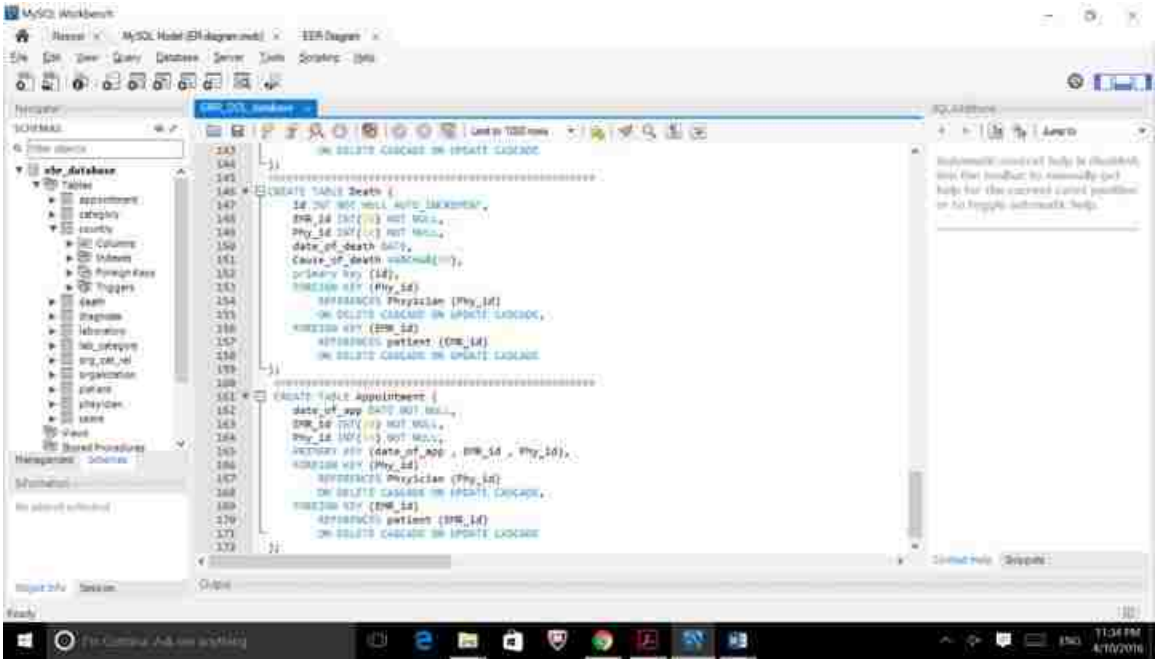


Figure 6.12 DDL of appointment table of EHR system

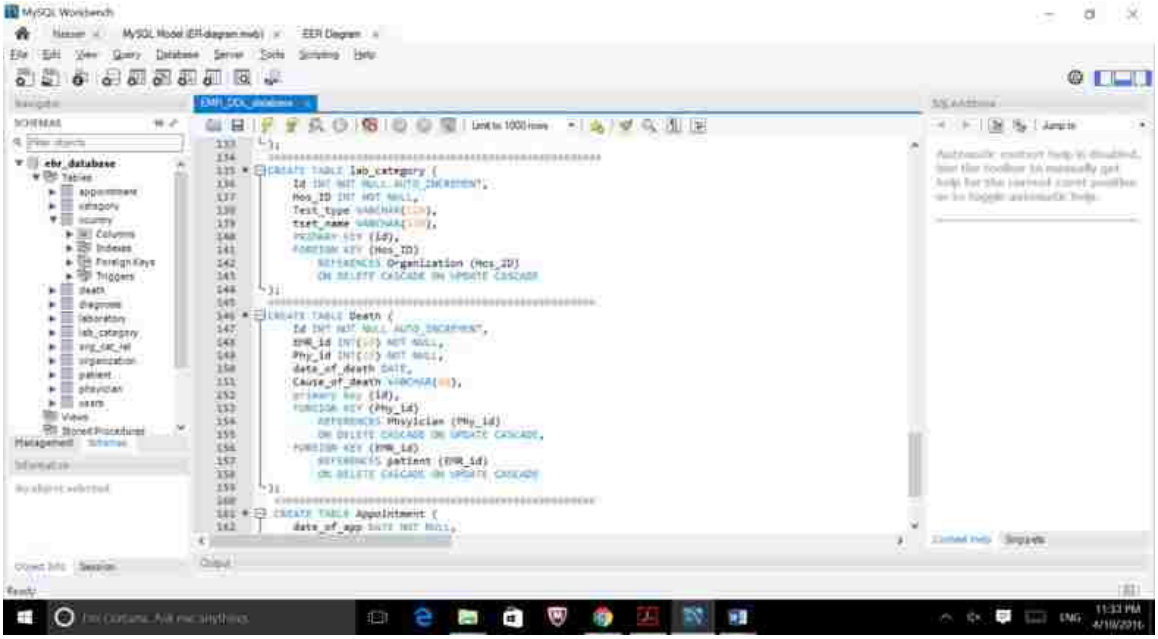


Figure 6.13 DDL of lab cat and death tables of EHR system

CHAPTER 7: CASE STUDIES

By the time our system design approach was being discussed, we already had a deep and extensive understanding of the system, having seen how it facilitates physician and patient interaction with the system to have a clearer understanding on the functionality of the system. In order to illustrate the use of system via patient or physician and controlled by MOI/MOH, we can create a case study with three different scenarios using the previous design guidelines. By doing this, we can illustrate how a physician is able to check, diagnose, review an EMR patient whether that patient is physically present in the hospital or not, and also how the patient can maintain his EMR and use it.

7.1 EMR System Case Study

To start our case study we need to create an imaginary user. Let's say the person is called "Matt" who is a 65 years old. Matt lives in a small city in the Kingdom of Saudi Arabia and he has a diagnosis of T4 N3 M1, which is an advanced cancer stage. The hospital where Matt has received treatment is located in the capital city, Riyadh, which is three hours by airplane, and he need to visit every week for tests and check the results, and also set up a new appointment. We can have another user, let's say he is Adam. Adam is the physician that follows up on Matt's health conditions, and needs to see the vital organs body tests every time he visits and schedule/approve a new visit appointment. On the other hand, David is the MOH/MOI authorized user to add and register Matt and Adam into the EMR system.

7.2 Scenario 1: Access to my EMR as patient

In the current situation Matt is not able to access his EMR at all in Saudi Arabia hospitals. The EMR systems that run there were only designed and implemented to serve the single healthcare provider only. Using our system Matt will be able to sign up to have an account. After Matt has his account created, there will be no data available until he visits the registration healthcare provider office to validate his identity. When the validation completes Matt's data and information will be added to the system via the registration employee at the hospital. Now, Matt is able to login and check his home page information, search his name, ID, and BOD. Also, Matt is able to see the current and previous diagnosis, laboratory, radiology results, and schedule a new hospital visit. Furthermore, our system provides for an interaction platform where he can directly communicate with his doctor. This will help the doctor stay in check with the patient and ensure that Matt consistently takes his medication as prescribed by him even when they are miles away. Based on the fact that our system is secure and safe, Matt is assured that the information that he has provided cannot be accessed by any unauthorized persons. The chats and calls are also secure and Matt will not have to worry about the security of his health information.

Since both Matt and Adam can communicate with each other via the communication platform provided by the system, Matt will not have to fly from his city to book an appointment in Riyadh in order to get medication. Moreover, he will not have to travel to Riyadh to get his body test results, since all these will have been facilitated by the system. By not traveling to Riyadh, Matt will not only have saved time but also saved

on extra costs that would have otherwise been spent on transportation. Traveling with health conditions is often not advisable by doctors because emergencies can come up that require immediate attention. The time and money that Matt could have spent traveling to Riyadh can now be channeled towards more important things, such as taking care of his family. Also, Matt will increase his relationship with Adam, since they will be able to constantly communicate with one another.

7.2 Scenario 2: physician diagnoses and treats patient

Currently, Adam as a physician is able only to add or check the local EMR patients that reside in the local hospital database that he works for. Also, he diagnoses his patients using the paper-based system first, then after he finishes his cases, he enters their data into the system after he finishes his work because the system is local and connect to their computer that is located in their offices. So, when Matt as a patient visits Adam at the hospital, Adam needs to ask Matt to do the tests and examinations of body again from the beginning. Clearly, this is a long process and tiresome to both Matt and Adam. However, all these challenges can be improved by our system. Using our EMR system that will be available on the cloud will open new connection sources for Adam to enter patient diagnoses and retrieve EMR patients at any time and from everywhere the patient visited. By accessing Matt's information at any time and entering the information directly into the system, he will save much time and be able to attend to more patients. Moreover, the system will enable Adam to not only have access to patient information residing locally, he will also be able to access information of patients from other states

and cities such as Matt. Furthermore, Adam will not have to carry out tests each time Matt visits since he will have access to all the information in the system and can ensure continuity of care efficiently.

7.3 Scenario 3: New physician register at hospital

Today, when a new physician starts working in a hospital in Saudi Arabia, the registration process is approved by the same hospital. Also, the authority and access to EMR patient is granted by hospitals or the healthcare provider itself. In the registration process, first the information is entered on paper before being typed and transferred to the system. This manual process raised a lot of concerns, especially regarding the security and safety of health record information. Actually, several cases were reported of missing information or wrong date entry. These issues therefore reduced the authenticity of the system. However, these challenges will be mitigated by the implementation of our system. Our system is highly secure and safe thus security issues will not be experienced at any given time. Similarly, through our proposed system, there will be access control to patient data to more secure levels, led by MIO/MOH. In this case scenario, when a new physician starts his registration to start working at a hospital, the first step that he or she will be needed to do is to send a request to MOI/MOH with complete details and the authorized employee at MOI/MOH to add him to the system after the agreement is signed. Also, any change in physician data or information requires a request to be sent to MOI/MOH. In this way the registration processes will have been eased and security enhanced.

CHAPTER 8: CONCLUSION AND FUTURE WORK

The electronic medical record system described in the above research provides important insights and solutions for the most commonly experienced challenges accrued from the paper-based medical record system. Currently, no single EMR system integrates EMR systems used in different healthcare facilities in Saudi Arabia. The inconsistency experienced from the use of different EMR systems provokes the need of having a single integrated EMR system that is used by all healthcare facilities in Saudi Arabia. The differentiation of implementing the EMR system often leads to incompatibility, which prevents the cooperation between healthcare providers and also the efficient use and analysis of data, which can be gathered from different locations or systems. However, the proposed integrated single EMR system on a cloud-based system will not only enhance consistency in healthcare service provision in the country but would rather enhance the efficiency, speed, accuracy, and effectiveness of healthcare operations.

8.1 Summaries of Contributions

The most significant aspect of this research thesis regards the implementation of the electronic medical record (EMR) on a cloud-based system to enable the improvement in health information technology. In seeking the solution for this research thesis, the researcher compiled a range of existing past literary materials on the subject matter and did an evaluation of the current uses of the system in different countries with much focus on Saudi Arabia. Before settling on the cloud-based system, the researcher examined

different systems, categorized them based on their usage, benefits, and efficiencies. After extensive evaluation, the cloud-based system was deemed appropriate for both public and private health facilities in Saudi Arabia. It was chosen based on the significant recent trend that cloud technologies can facilitate, which is the availability of data regardless of the patient, clinician, or physician's location. Similarly, these technologies enable a linkage and utilization of the health information exchange (HIE) by healthcare researchers and providers to invest in data through online and offline cooperation. It is important to support the standardization of the EMR system on cloud-based technology because it will minimize or at best prevent human's errors, repetition or duplication of records, and reduce the cost of operation and time.

To summarize, the major contributions of this thesis include:

- The researcher compiled a list of the currently used health record systems and the types of technologies used to support the systems.
- It was identified that the currently used health records systems encountered a lot of problems especially regarding consistency; it was prone to human errors; they consumed a lot of time since they were manually operated; and there were several instances of duplication or repetition of records; the high cost of operations; reduced efficiency and speed.
- Similarly, the currently used technologies were identified as not the most appropriate since they did not enhance the health records systems.
- The researcher designed the use of the cloud technology in supporting a single electronic health record system for all public and private healthcare facilities in Saudi Arabia. This system is the most ideal as it can support data availability

regardless of the clinician, patient or physician's location. Furthermore, the proposed system enables utilization and linkage of the health information exchange by healthcare providers to invest in data through offline and online cooperation. With the implementation of this system, there will be a reduction in human errors, duplication of records and reduced operation time and cost.

8.2 Broader impacts

The implementation of this system technology will not only accrue short-term benefits, but will also accrue long-term benefits. The immediate short-term benefits of the system are that it will provide healthcare providers with complete and accurate information about the patient's health, thus enabling them to provide the best possible care. It provides a platform for sharing information with the family and patients, thus enabling patients and families to take part in the decisions about their healthcare [23]. Furthermore, there will be reduced clinical errors, reduced paperwork and filing cabinets, increased legibility of notes, multiple users can access files at the same time as well as increased supervision and oversight of filing procedures.

Similarly, it should be noted that this system also has long-term potential to reduce operational costs incurred in healthcare provision. The system greatly cuts costs, as it is less labor intensive, fast and accurate, and saves on time; thus, a lot of operations can be carried out within a short duration of time. The system will also enable integrating data and billing. In the long-term, the system will also increase the efficiency and consistency in health service delivery [23]. This will not be realized in the early stages of

the system adoption, however, once implemented and well understood by the users, efficiency and consistency will be realized as all healthcare facilities, both public and private, will have the system and can access similar information regardless of their location. Furthermore, the system will improve safety and security of patient health information as it provides restrictions to unauthorized persons.

8.3 EHR System Future Work

The EHR system as cloud technology will provide the access to the system as web services as the first step of this project. However, much future work needs to be developed to complete such a project in developed countries. New technologies and methods are available today either as ideas or works for adapting.

Mobile application is one of the most exciting areas for E-healthcare developers today in regards to how they could provide the access for patients. Transformation from web services to mobile technology will facilitate and widen the use of EHR systems. Based on that, Saudi's government should pay much attention to this area.

Bring your own Device (BYOD) is referring to the policy that permits employees to bring personally owned mobile devices to the workplace. Using the centralized EMR will facilitate the implementation of BYOD. The advantages of such a service will reduce the patient waiting time, especially in the emergency cases, and physicians will have more time to check more patients.

The Saudi government is actively seeking to integrate and connect government services together to achieve the e-government approach. Implementing the centralized

EMR by MOH will provide for the ability for either public or private sectors to interact with it, for example, cooperation between the Ministry Of Interior (MOI) and Ministry of Health (MOH) to check and verify the identity of patients, especially since the MOI has the complete database for the citizens and aliens fingerprints. Furthermore, adding the fingerprint in EMR is also a consideration to increase privacy and security, as a new trend in health care technology.

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Appendix A

Glossary of terms

Term	Definition
EMR	Electronic Medical Record is the file that include patient information.
PHR	Personal Health Record is used exchangeable with EMR however it is more about patient history visits
MOH	Ministry of Health
MOI	Ministry of Interior
HITECH	The Health Information Technology for Economic and Clinical Health
HIPAA	Health Insurance Portability and Accountability Act
HIMSS	Healthcare Information and Management Systems Society
HIE	Health Information Exchange is the way that EMR is exchanging between healthcare providers