Title :   Infectious diseases management framework for
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INFECTIOUS DISEASES MANAGEMENT FRAMEWORK FOR SAUDI ARABIA (SAIF)

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Fahad Alanezi

ABSTRACT

Infectious disease management system area is considered as an emerging field of modern healthcare in the Gulf region. Significant technical and clinical progress and advanced technologies can be utilized to enhance the performance and ubiquity of such systems. Effective infectious disease management (IDM) can be achieved by analysing the disease management issues from the perspectives of healthcare personnel and patients. Hence, it is necessary to identify the needs and requirements of both healthcare personnel and patients for managing the infectious disease. The basic idea behind the proposed mobile IDM system in this thesis is to improve the healthcare processes in managing infectious diseases more effectively. For this purpose, internet and mobile technologies are integrated with social networking, mapping and IDM applications to improve the processes efficiency. Hence, the patients submit their health related data through their devices remotely using our application to our system database (so-called SAIF).

The main objective of this PhD project was the design and development of a novel web based architecture of next-generation infectious disease management system embedding the concept of social networking tailored for Saudi patients. Following a detailed literature review which identifies the current status and potential impact of using infectious diseases management system in KSA, this thesis conducts a feasibility user perspective study for identifying the needs and the requirements of healthcare personnel and the patients for managing infectious diseases. Moreover, this thesis proposes a design and development of a novel architecture of next-generation web based infectious disease management system tailored for Saudi patients (i.e., called SAIF – infectious diseases management framework for Saudi Arabia). Further, this thesis introduces a usability study for the SAIF system to validate the acceptability of using mobile technologies amongst infected patient in KSA and Gulf region. The preliminary results of the study indicated general acceptance of the patients in using the system with higher

usability rating in high affected patients. In general, the study concluded that the concept of SAIF system is considered acceptable tool in particularly with infected patients.

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Finally, I would like to thank all of those who have helped me and showed their support. They are always in my mind and with my best wishes

DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of Bedfordshire.

It has not been submitted before for any degree or examination in any other University.

The following papers have been published (or submitted for publication) as a direct result of the research discussed in this thesis:

1. F. Hussain, and F. Alanezi, "A Potential Implementation of Citizen-Focused E-Health Strategies Framework for Saudi Arabia", International conference on Biomedical and health informatics, 2014.

2. F. Alanezi, and H. Qing, "Infectious Disease Management Systems in the Gulf Region: The Current Status and Potential Impact" 15th International Symposium on Distributed Computing and Applications to Business, Engineering and Science (DCABES 2016).

3. F. Alanezi, and H. Qing, "A Study on Perception of Managing Infectious Disease through Social Networking in the Kingdom of Saudi Arabia", 15th International Symposium on Distributed Computing and Applications to Business, Engineering and Science (DCABES 2016).

Name of candidate: Signature:

Date:

ABBREVIATIONS

AAFP	American Academy of Family Physicians
AIDS	Acquired Immune Deficiency Syndrome
API	Application Programming Interface
CAT	Computerized Axial Tomography
CSS	Style Sheet Language
DSF	Django Software Foundation
ECTA	E-commerce Technology Acceptance Model
EIU	Economist Intelligence Unit
ESEC	E-health System Evaluation Criteria
GUI	Graphical User Interface
Haj	Annual Pilgrimage Season
HIS	Hospital Information Systems
HIV	Human Immunodeficiency Virus
HTML	HyperText Markup Language
IBM	International Business Machines
ICT	Information and Communications Technology
IDM	Infectious Disease Management
ISSM	Information System Success Model
IT	Information Technology
KSA	Kingdom of Saudi Arabia
MERS-CoV	Middle East Respiratory Syndrome Corona Virus Infection
MHealth	Mobile Health
MIS	Management Information Systems
MoH	Ministry of Health
MT	Mapping and Tracking Services
MVC	Model View Controller
MVVM	Model View-View Model
NGHA	National Guard Health Affairs
NMR	Nuclear Magnetic Resonance
PCHMS	Personally Controlled Health Management System

PDA	Personal Digital Assistant
PET	Positron Emission Tomography
QUAA	Quantitative data on the Usability, Acceptance and Adoption
RAD	Rapid Application Development Model
REST	Representational State Transfer
RT-PCR	Reverse Transcription Polymerase Chain Reaction
SAIF	Infectious Diseases Management Framework for Saudi Arabia
SARS-CoV	Severe Acute Respiratory Syndrome - Corona Virus
SMS	Short Message Service
SN	Social Networking Services
TAM3	Technology Acceptance Model Version 3
UAA	Usability, Acceptance and Adoption
UM	User Management Services
UML	Unified Modeling Language
WWW	World Wide Web

TABLE OF CONTENTS

x

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Introduction

Infectious diseases can lead to a major endemic or pandemic outbreak that could potentially have devastating outcomes. The world has experienced such devastating events through the time whether it is Black Death or the recent Ebola outbreak. Therefore, it is very essential and necessary to effectively manage the infectious diseases to prevent severe damages to the human life. The world is changing rapidly with new inventions and technology developments in different areas. Utilising effective technology solutions can help in managing the spread of infectious diseases more effectively. This research focuses on using web technology along with social networking module in developing the information system in order to effectively manage the infectious diseases in the region of Kingdom of Saudi Arabia (KSA).

This chapter provides an overview about the research project, motivation, objectives and the contributions to knowledge.

1.1. Research Overview

It is very important to effectively manage the infectious diseases as they might have potentially adverse effects on an individual or the society. The complications of infectious disease can range from minor to very serious conditions. Minor infections like cold or fever can be managed easily whereas serious infections like Ebola, or Middle East Respiratory Syndrome Corona Virus Infection (MERS-CoV) can be serious as they might affect human life in different ways including social, economic, political, environmental aspects. As the world faces new infectious diseases from time to time, it is very essential to have an effective infectious disease management system, which can be updated according to the changing conditions.

The seriousness of the infectious diseases should never be underestimated as the effects can be slow and steady or could be instant causing major disruption in human life. According to the World Health Organization Report [1], about 23% of the global deaths in the year 2012 are caused due to infectious diseases. Thus, managing infectious diseases is important. The major causes of deaths across the different income group countries [1] are compared in Figure 1.1. According to the data available, it is clear that about $2/3^{rd}$ of the total deaths have occurred in low and middle-income group nations. One of the major reasons for such increased deaths

in low and middle income group nations is due to poor availability of health data and the information systems [1]. Therefore, it is necessary to understand the country profile to design the infectious disease management system.

Figure 1.1 Major Causes of Death Globally.

A horizontal stacked bar chart titled "Figure 1.1 Major Causes of Death Globally." The y-axis lists causes of death and the x-axis shows Number of deaths from 0 to 140.

Cause	Low income	Lower-middle-income	Upper-middle-income	High income
Ischaemic heart disease	6	43	46	37
Stroke	8	35	55	22
COPD	3	23	22	7
Lower respiratory inf...	14	24	10	7
Trachea bronchus, lun...			13	14	11
HIV/AIDS	10	10	6	1
Diarrhœal diseases	8	17	2	2
Diabetes mellitus	2	10	10	5
Road injury	3	8	9	2
Hypertensive heart disease	1	6	9	5

Number of deaths

Legend:
- Low income countries
- Lower-middle-income countries
- Upper-middle-income countries
- High income countries

Complications that can have both minor and major impact on the population. For example, common cold, an infectious disease can be managed quickly though it can spread effectively. But some other disease causing agents like Ebola virus can very quickly cripple the infected person and kill them. The spread of Ebola is very rapid and mostly confines to a particular geographical area, due to its quick impact on the infected person [2]. Another disease causing agent such as Human Immunodeficiency Virus (HIV) has a slow impact as the virus slowly attacks the immune system of the infected person. As a result, there is a large possibility of spreading the disease as the infected person may not quickly knew that he is affected [3]. Another disease causing agent Polio Virus can cause infantile paralysis, and there is no cure for it. However, it can be prevented by multiple vaccinations during the childhood. Thus, for infectious disease management (IDM) it is necessary to identify that different diseases have

2

different characteristics and there is a scope for prevention of infectious disease. Therefore, it is necessary to understand the characteristics of different diseases and accordingly the disease management techniques can be developed.

Effective infectious disease management can be achieved by analysing the disease management issues from the perspectives of healthcare personnel and patients by adopting effective methods and by deploying the technology. It is necessary to identify the needs and requirements of both the healthcare personnel and patients for managing the infectious disease so that an effective approach could be developed. For example, lack of IDM guidelines or lack of knowledge of available IDM guidelines, poor infrastructure could be some drawbacks for the healthcare personnel in some regions. Similarly, lack of awareness among the people regarding the infectious diseases and precautions could be some major drawbacks for the patients/people. The rapid changes in the technology and increased research can help in developing effective methods by integrating the IDM approach and technology to result in an effective system for IDM.

Some of the major aspects of IDM are prevention and precautions. Both require knowledge and awareness amongst the people. Self-Management of diseases can be the first step towards defining an effective IDM approach. The main objective of Self-management education programs is to empower patients with the information, skills and techniques to improve self-care and doctor–patient interaction, preventing the spread of infectious disease, effectively managing the disease by the patient, with an ultimate goal of improving quality of life [4]. For an infected person, the self-management technique can help in effectively fighting against the disease, and for a normal person it can help as a preventive mechanism. In both ways, it is very effective for managing the disease. However, attempts to promote self-management resulted to be failures in some countries due to inadequate integration to healthcare, and it is suggested that engagement of healthcare professionals is very essential for the success of self-management activities [4, 5]. The self-care approach is a complex process as it requires patients to change their lifestyles, which usually include taking preventive and precautionary methods like regular exercise, maintaining body weight, having balanced diet, ensure hygienic surroundings, regular intake of medicines and follow-up etc.

Various studies [6-9] have shown that knowledge and awareness is an essential factor in the self-management approach. Therefore, various means to educate the people and patients

are to be identified and implemented. As stated earlier, the role of healthcare personnel is important in this aspect for educating the patients. In addition, as outlined in the Ontario's framework, self-management techniques can be integrated with information systems for preventing and managing the chronic diseases [10]. However, other behavioural management techniques like motivation, increasing self-confidence can also be considered as self-management approach for effective results.

Adoption and application of technology is of high significance in healthcare services as it not only improves the healthcare processes but also minimises the costs. It is also called as eHealth andrefers to the healthcare practices assisted by the communication systems and electronic processes. The eHealth technology assisted by mobile devices are generally used to capture, analyse and transfer health related information and is often referred to as Mobile Health (mHealth) [11]. Adopting mHealth technologies can integrate subjective, physiological and diagnostic data in real time and can increase remote access to diagnostics and treatment support, and can also be used for geographical mapping for better analysis of disease spreading. It also provides knowledge based disease management and improves outcomes. Due to the several potential benefits, it is considered as the future of healthcare [12].

Though there are many studies conducted globally in analysing the IDM with the self-management techniques and mHealth techniques, most of them are disease specific and there were no studies found in this aspect in the Kingdom of Saudi Arabia, which is the main subject of this thesis [6-10]. There are different challenges being faced in KSA in the process of managing infectious diseases. International tourism centre, especially the hajj, has been a major concern for the rapid spread of infectious diseases as tourists from different parts of the world visit the city. It is a large country with villages and cities scattered all over and there has been a rapid growth in the population and as a result it has been a challenging factor to control the spread of infectious diseases. In addition, wide and strict religious practices including social and cultural issues restrict the effective implementation of healthcare management models. Other concerning issues include rapid increase in the complicated diseases like obesity and coronary diseases which might lead to other health problems, unhealthy food habits and lack of knowledge of healthcare self-management among the population, high prevalence of smoking, and lack of nation specific guidelines embedding the regional and cultural factors in the healthcare management [13].

Globally, the country`s population has one of the highest number of mobile phone and social network users. There are about 51 million mobile users by the end of 2013 as shown in, and the number of mobile subscriptions were found to be 180 per 100 people in 2014 [14]. There are about 20.8 million internet users with a penetration rate of 64.7% in 2016 [15] as shown in

Figure 1.3. Social Networking is also becoming increasingly popular in the country, with WhatsApp on the top of the list with 27% penetration rate followed by Facebook (25%), Twitter (20%), and Skype (14%) [17]. Though the penetration of internet and mobile technologies is high in the country, the advantage of it has not been utilised effectively in the healthcare management of IDM. In addition, to the best of the researcher's knowledge there is no feasibility study conducted on the mobile intervention for IDM.
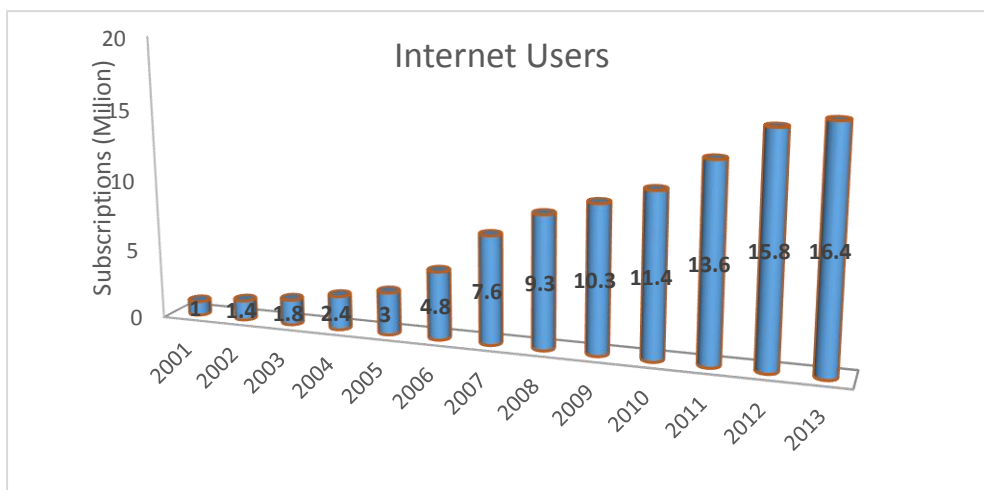
Figure 1.2 The Mobile Users in Saudi Arabia [16].

Figure 1.3 The Internet Users in The Kingdom of Saudi Arabia [16].

The basic idea behind the mobile IDM system is to improve the healthcare processes in managing infectious diseases more effectively. For this purpose, internet and mobile technologies are integrated with social networking, mapping and IDM applications to improve the processes efficiency. The patients submit their health related data through their devices

5

remotely using the application to our system database (called as SAIF). They can also access their health related information from the database using the application and view it using GUI tools. The patients can also participate in social networking where they can interact and share information with other patients. The patients' health data will be reviewed by the nurse/physicians, and accordingly the personalised feedback is given to the patients. The patients are also provided with educational resources to increase their awareness about the diseases and to improve their medical condition. There is a Mapping module in the system, which allows the physicians of healthcare personnel to view the infectious diseases on a geographical map, and exactly pinpoint the location. Mapping technique can be used to identify the spread of infectious disease, and this information can be used by the decision makers and healthcare officials to take necessary steps. Overall, the mobile IDM System helps in managing the infectious diseases at the patients end by providing educational and motivational support through social networking platform and help the decision makers to effectively analyse the spread of infectious diseases geographically which can help them in developing counter strategies to prevent the disease spread.

1.2. Motivation

Out of the 354 generic infectious diseases worldwide, about 213 are endemic or potentially endemic to Saudi Arabia [18], which shows high prevalence of infectious diseases in the country. Out of these 213 infectious diseases, information regarding only 10 diseases is placed on the Ministry of Health Website. Additionally, very few studies are found which are focusing on the IDM in Saudi Arabia. The country being a tourist centre for hajj pilgrims, accommodates the largest gathering on the earth annually and is highly prone to infectious diseases. A recent study [19] has shown that infectious diseases are the major threat in the country and are the major cause of morbidity. The control measures in the region have shown success in few instances, but have shown poor impact in many instances.

In another study [20], it was found that 26-45 age group people are the most affected with infectious diseases. Pneumonia, PUO, Pulmonary TB are the most common infectious diseases which are commonly found in the hospitalised patients. Pneumonia and UTI were found to be more prevalent among females while pulmonary TB, bronchopneumonia, meningitis, and malaria among males [20]. The recent outbreak of coronavirus (such as MERS-CoV) has identified various drawbacks in the healthcare management and IDM in Saudi Arabia. It was found that poor communication and a lack of accountability in government

departments, inadequate state oversight and a failure to learn from past mistakes have all hindered the country's approach in fighting against the virus spread [21]. It was also observed that lack of control over complete healthcare management by the Ministry of health, lack of proper healthcare policies and guidelines, poor communication, and poor infrastructure are the major causes of poor IDM in Saudi Arabia. Additionally, limited research in this area and lack of complete information access to the international scientists has also made the situation further worse.

Additionally, there are very few studies found in the aspect of IDM in Saudi Arabia. Considering these major healthcare challenges in the region has motivated this study to design and develop a mobile IDM system by integrating the social networking, mapping, behavioural change concepts, tailored according to the needs and requirements of healthcare professionals and the patients in Saudi Arabia.

Due to the increasing number of visitors to KSA especially during Haj season, such systems are needed to be developed in Saudi Arabia. Because there is a lack of web services and due to the management difficulties faced while hosting millions of possible patients, such systems are substantially needed. Hence, this research focuses on using web technology along with social networking module in developing the information system in order to effectively manage the infectious diseases in the region of Kingdom of Saudi Arabia (KSA).

1.3. Aims and Objectives

The aim of the research is to develop an IDM system tailored for the Kingdom of Saudi Arabia (KSA). The objectives to achieve the aim are:

- To conduct a technology and systematic user perspective study for identifying the needs and the requirements of healthcare personnel and the patients for managing infectious diseases in KSA.
- To design and develop a new architecture of next-generation web based infectious disease management system embedding the concept social networking.
- To conduct a usability study which will include performing empirical and perceptual investigations of the e-health system as well as including a validation measurement for SAIF system adoption, acceptance and usability as an approved e-health management system in health sector organisations.

1.4. Contribution of the Research

The thesis presents an information system based framework that is developed to effectively manage the infectious diseases in the region of Kingdom of Saudi Arabia. A detailed feasibility and systematic user perspective study for identifying the needs and the requirements of healthcare personnel and the patients for managing infectious diseases in KSA was conducted to identify the current status and potential impact of using Infectious diseases management system. The study also included design and development of an architecture for next-generation web based infectious disease management system that included a social network as an integral part. The development led to achieve an infectious diseases management framework for Saudi Arabia which we name as SAIF, addressing the main challenges that were identified in the literature review and in the context of KSA. Further, a usability study was conducted that performed empirical and perceptual investigations of the e-health system as well as included a validation measurement for SAIF system adoption, acceptance and usability as an approved e-health management system in health sector organisations.

The major contributions of this thesis can be summarized in the following:

(1) A detailed literature systematic review to identify the current status and potential impact of using Infectious diseases management system embedding social networking in the gulf countries, particularly in the kingdom of Saudi Arabia.

(2) A preliminary study on the perceptions with the focus on Saudi patients and medical staff requirements and the needs of the Infectious diseases management in KSA.

(3) Design and development of an Infectious diseases management system tailored for Saudi patients (SAIF – infectious diseases management framework for Saudi Arabia).

(4) A preliminary usability study on evaluating the SAIF system in the KSA and in analysing the aspects of user satisfaction and interaction.

1.5. Thesis Structure

The rest of this thesis is structured as follows:

Chapter 2: Literature Review: This chapter discusses the concepts of Infectious diseases management in general and its challenges in Saudi Arabia. It also presents the following literature review studies relevant to this work (i) a general review of Infectious diseases management system, (ii) a detailed review of the previous and the current status of Infectious diseases management system embedding social networking in the Gulf region, (iii) a review of

social networking for Infectious diseases management and a detailed discussion to provide the gap of knowledge and why this study is timely and important.

Chapter 3: Infectious Diseases Management Framework for Saudi Arabia (SAIF): This chapter explains the series of concepts used for building the SAIF framework, which includes requirement analysis and the processes deployed for gathering the requirements, the architectural design of SAIF and the deployment tools to be used.

Chapter 4: SAIF: This chapter introduces the implementation and testing of the SAIF project, which aims to manage infectious diseases, makes use of the social network, and provides smart maps and statistics for the policy makers associated to the spread infectious diseases and patient status in an area.

Chapter 5: Usability Study of SAIF System: This chapter introduces a comprehensive evaluation for the usability acceptance and the adoption of the e-health service system SAIF in KSA, which is based on user experience. In addition, it evaluates key factors in user experience that affect the usability, acceptance and adoption (UAA) of SAIF in KSA and the interaction of its social network blogs with e-health systems.

Chapter 6: Conclusions: This chapter concludes the works presented in this thesis and points out potential future works.

Chapter 2: Literature Review

In this chapter, an overview about the infectious diseases, infectious diseases management systems worldwide, infectious diseases management systems in the gulf region, and social networking for healthcare.

2.1. Infectious Diseases

2.1.1. Definition

Infectious diseases are the disorders caused by the organisms, and they are transmissible or communicable from a person to the other [22].The medium of transmission can be through air, water, food, or in direct contact with the infected body. However, there are different routes of transmission, which might need different medical conditions to treat the infected persons [23]. These disease causing agents include different micro-organisms like virus, bacteria, fungi, and parasites. Usually many transmitted organisms live within the body, and they might be harmless. But under certain conditions they can be harmful, leading to disorders that could lead to acute or chronic disorders [24].

2.1.2. Symptoms

Usually, the symptoms depend on the type of infection and the disease causing agent. Some symptoms can be general and affect the whole body like fever, fatigue, weight loss etc. While other symptoms can be limited to a particular part like running nose, skin rashes etc [25]. In some cases, a disease can be asymptomatic (no symptoms observed), or can take long time to identify symptoms [26]. However, symptoms are not symmetric with organisms as the symptoms are specific to disease causing agent. For example, the symptoms of chickenpox caused by viral infection include fever, and rash resembling water blister appearing after 3-4 days, while the symptoms of common cold caused by viral infection include watery eyes and running nose.

2.1.3. Causes

Infectious diseases are caused by micro-organisms that are transferred to the host body through different mediums. The ways of transmission could be through direct contact or indirect contact, as depicted

. The direct contact can be a person to person type, or animal to person, or mother to an unborn child [27]. Person to person contact can include disease transmission from an infected person to the healthy person through touch, exchange of bodily fluids through sex, coughs. In Animal to person type, it could be through a bite or a scratch by an infected animal or even by the contamination of animal waste [28]. In mother to unborn child, the disease may be directly transmitted to the unborn child. Indirect contact can be through insect bites, food, air, and water contamination [27].
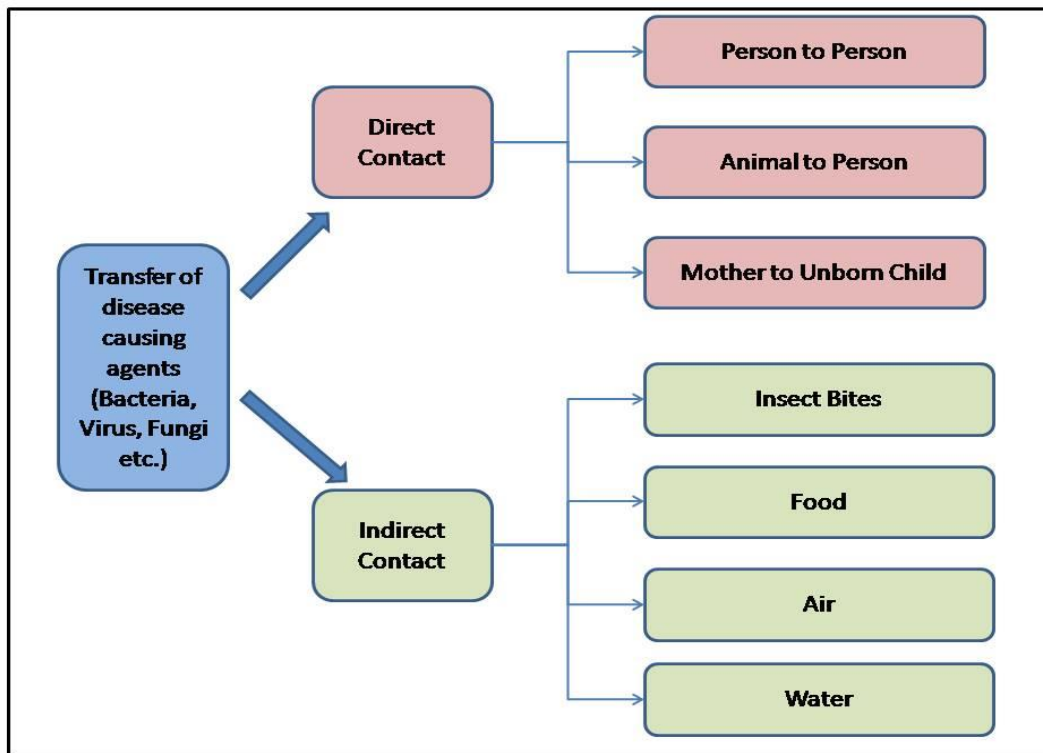
2.1.4. Risk factors

There are different risk factors associated with developing of an infectious disease. As man is a social animal and involves actively in social participation, the risk of getting infected is high. However, the infection depends on the person's immunity, behaviour (ex. Taking steroids,

drugs, sports, improper diet), and other external factors medical transplants, blood transfusion etc. Socio-economic and political factors like globalization, illiteracy, ageing population, poverty, urbanization are other external factors which might influence in the rise of infectious diseases[29, 30]. The risk or impact on the outbreak of an infectious disease can have an adverse impact on the social and economic life. The recent outbreak of Ebola, caused by viral infection is an example of it [31].

2.1.5. Complications

The complications of infectious can vary from minor to serious conditions. Some infectious diseases like running nose and diarrhoea have minor complications as it might lead to headaches and dehydration respectively; while others like AIDS (Acquired Immune Deficiency Syndrome), pneumonia can have greater complications as the infected person are prone to many other diseases as they directly affect the immunity of the person. Some infections are also linked to developing long term risk of cancer (Human papillomavirus is linked to cervical cancer) [32]. Though the regular immunization can help in minimizing the complications, it is necessary to develop the immunization therapy in by considering risk factors in association with the complications [33].

2.1.6. Tests and diagnosis

The diagnosis of the infectious disease involves identifying the infectious agent. Different tests are used in this process. Symptomatic diagnosis is the process of identifying a disease by observing the symptoms; however additional test might be required to confirm the disease. Microbial culture, microscopy, biochemical tests are used in the diagnosis process of infectious diseases. Common tests include blood tests, urine tests, stool sample etc. for identifying the disease causing agents. Other techniques like X-rays, CAT (Computerized Axial Tomography) scans, Positron Emission Tomography (PET) scans or Nuclear Magnetic Resonance (NMR) are also used in this process [34, 35].

2.1.7. Treatments and drugs

The infectious diseases can be treated by anti-ineffective drugs which can supress the infection. These drugs are classified for different types of infections and include antibiotics, antiviral, anti-fungal, anti-parasitic. These drugs can be given to the infected persons either through tablets or injections or applied topically through ointments or gels. Antibiotics can be used only for bacterial infections and they do not have any impact on viral infections. The increased use of antibiotics is leading to bacteria that develop resistance to antibiotics, which is one of the

major concerns involved. Antivirals are the drugs used for viral infections. However, not all viral infections can be cured by anti-virals. Diseases like AIDS, Hepatitis C, and Hepatitis B have no permanent curing drugs. Fungal infections are mostly seen on skin, and mucous membranes of the mouth and throat. Anti-fungals are used for treating fungal infections. Diseases like malaria, caused by tiny parasites are treated using the anti-parasitic drugs [36-38].

The treatment of the infectious diseases can be extensive or intensive based on the severity of the disease. However, overuses of anti-infective drugs are leading to the development of drug resistive organism or disease causing agents.

2.1.8. Prevention

Different preventive measures are developed in general for controlling the spread of infectious diseases or for getting infected. General preventive measures include maintaining cleaner surroundings, wearing gloves, washing hands, taking nutritional diet, which can be done on the personal behalf. Other measures include immunization for preventing different diseases. Anti-microbial substances like antiseptics, disinfectants and antibiotics can be used when necessary. Preventive measures also include taking care on personal behalf by getting an advice from a doctor while travelling, learning and adopting preventive measures through different means [39, 40].

2.2. Infectious Diseases Management

2.2.1. The importance of Infectious Diseases Management

It is very important to effectively manage the infectious diseases as they might have adverse effects on an individual or the society if not managed. The infectious disease management can be specific to the types of diseases or to the institutions like hospitals or clinical care centres or schools, or to an individual or a family. The infectious disease management can be discussed in the following categories:

Institution Specific: Institutions like hospitals, primary care centres, schools, colleges are highly prone to infectious disease as the people from different regions interact and contact with each other. Therefore different safeguards are laid down with respect to the institutions in managing the infectious diseases. For example, creating the awareness of infectious disease management among the students in schools by providing cleaner surroundings and information like the need for hand washing, protective clothing, personal hygiene, respiratory hygiene and

cough etiquette, preventing blood and bodily fluid exposures, management of cuts, nose bleeds and bites etc. can help in minimising the infections [41]. Primary care centres and hospitals can also participate in infectious disease management by support to patients from the GPs in achieving health and well-being, restrictive antibiotics prescribing according to the seriousness of the disease etc. [42].

Personal Management: The people can participate in the infectious disease management by maintaining personal hygiene, cleaner surroundings in the home and locality, taking preventive measures like hand washing, vaccination, pets vaccination etc. The hygiene practices would ensure protection in preventing the infectious disease spread in the family and the locality.

Community practices and programmes: Different community programmes are designed to manage infectious diseases. For example, the Family Doctor and Nurse Program in Havana region, where the doctor along with the nurse visits the community twice a year and records the medical information of the people including vaccination, health, nutrition, diseases etc. helped the local authorities continuous assessment and risk evaluation of different diseases and maintaining quality health [43].

Policy formulation and Regulating authorities: Policy formulation helps in specifying guidelines to the people, agencies and institutions in effectively managing the infectious diseases. The guidelines give an easy approach in ensuring the direction to follow for disease prevention and control. Different governments in different nations have specified different guidelines for infectious disease management and prevention. For example, Department of health and ageing of Australian government has specified Infection control guidelines, disease specific management guidelines like scabies management guidelines, and Australian guidelines for prevention and control of infection in healthcare etc. [44-46].

An effective Infectious disease management requires an effective preventive and control strategy involving all the above mentioned areas and aspects, and it is very important to manage, as few disease outspread can cause various major problems like the recent outbreak of Ebola.

2.3. Challenges of Infectious Diseases Management in the Kingdom of Saudi Arabia

2.3.1. Overview

The Kingdom of Saudi Arabia is one of the largest Arab states in the Middle-East, which has a national healthcare system. The Ministry of Health (MoH) is the major agency dealing the implementation and managing of healthcare services in the country. It is one of the important places of international tourism; mainly the hajj tourists from different parts of the world visit the country on a pilgrimage. As there is vast moment of international tourists the possibility for the spread of infectious disease is very high in the KSA. However, the MoH has been taking various steps and formulated guidelines for the prevention and control of infectious diseases [47-49].

2.3.2. Challenges

There are different challenges being faced in KSA in the process of managing infectious diseases. Figure 2.2 illustrates the challenges in managing the infectious diseases in KSA. International tourism centre, especially the hajj, has been a major concern for the rapid spread of infectious diseases as the tourists from different parts of the world visit the city. In addition there are other major challenges, which include the following [54]:

- It is a large country with villages and cities scattered all over and there has been a rapid growth in the population, as a result it has been a challenging factor to control the spread of infectious diseases.

- Wide and strict religious practices including social and cultural issues restricting the effective implementation of healthcare management models.

- High dependence on expatriates to work in the hospitals and healthcare models raising the cultural problems in the delivery of healthcare services by the expatriates.

- Rapid increase in the complicated diseases like obesity and coronary diseases, which might leads to other health problems.

- Unhealthy food habits and lack of knowledge of healthcare self-management among the population.

- High prevalence of smoking.

- Lack of nation specific guidelines embedding the regional and cultural factors in the healthcare management.
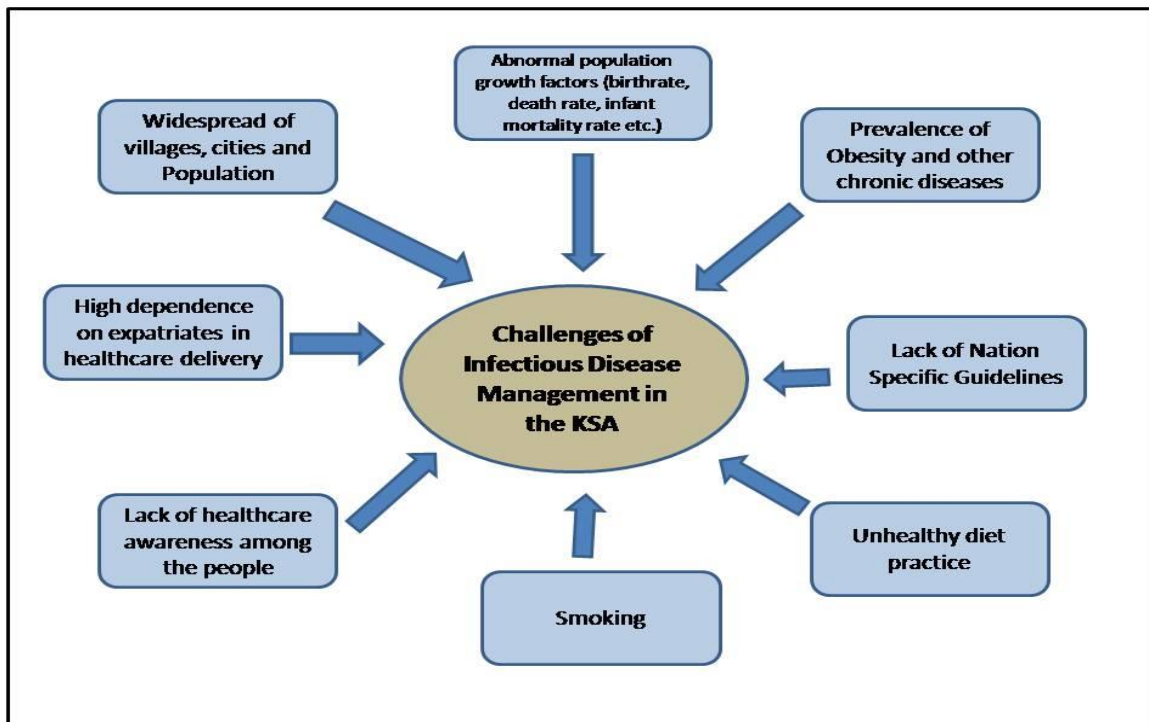
Figure 2.2 Challenges of Infectious Disease Management in KSA.

2.3.3. Airborne infectious diseases (Coronavirus)

Airborne infectious diseases are those in which the disease causing pathogen is transmitted through air. The Coronavirus infections are commonly found among humans. The types of Coronavirus [55] which affect humans are shown in   Figure 2.3.
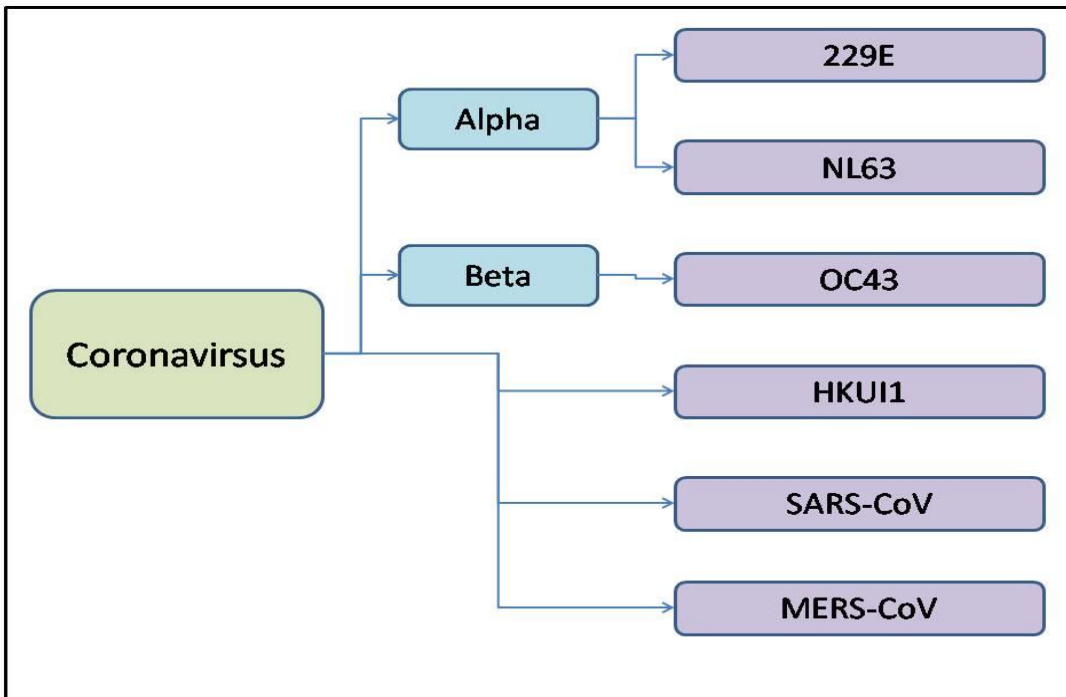
Figure 2.3 Coronavirus.

Among these Severe Acute Respiratory Syndrome - Corona Virus (SARS-CoV) and MERS-CoV are recently found and caused many deaths across the world. The recent outbreak of coronavirus infectious disease referred as MERS-CoV has been a source of tension to different nations as the cases has been found in many regions of the world, where the infected people are either in Middle East or those who travelled to Middle East. It is spread through air with respiratory droplet secretion. The elderly people with pre-medical conditions like diabetes, coronary disease are at risk of severe infection. The major risk factor is close association with an infected person. However, the risk of transmission is considered to be low, as large number of virions have to be inhaled to get infected [50-52].

The initial symptoms of the disease include fever and mild cough. The breathing disorder continuous to progress causing dyspnoea and hypoxia (inability to maintain oxygenation). This progression can be taking several days or it could be rapid depending on the pre-medical conditions of the infected person. The virus also infects other organs in the body including lungs, kidneys, heart, causing the disruption in their functioning. The disease is diagnosed using the reverse transcriptase polymerase chain reaction (RT-PCR) test. The patient's history could make the MERS diagnosis more likely. Other tests like X-ray, CT-Scans can also be useful for

17

diagnosing the disease to an extent, as the infected person can be referred for RT-PCR test [50, 51].

As there is no sufficient experimental data, the treatment for the disease is more towards providing the support for disorders like oxygen supplementation and mechanical ventilation, rather than towards a curative approach. Different medications are put on trials, but without conclusive benefits. In addition, the treatment has to be adjusted according to the patient's pre-medical conditions [50].

As MERS-CoV does not spread rapidly, protective measures can be taken in preventing the further outbreak of the disease. Avoiding close contact with the infected persons, a wearing masks, gloves, regular hand washing, avoiding bodily fluid exchanges are few preventive measures that can be followed. However in hospitals and care centres, the infected person has to be kept in an airborne isolation rooms. The care takers and the physicians should wear masks, gloves and cover their eyes while treating the patients [51-53].

The Ministry of Health in Saudi Arabia has developed an effective strategy in managing the MERS-CoV, with a well-defined approach. An algorithm is designed to manage patients with suspected MERS-CoV. Standard precautions are devised for patients, care takers, and the common people to prevent the outbreak of the disease. Rigorous standard procedures are established for collection, transport of the specimens for diagnosis. The guidelines feature all the possible and necessary preventive measures that can be taken in order to manage the disease with the existing conditions [53].

2.4. Infectious Disease Management Systems across the globe

2.4.1. Review of Major Infectious Disease Management Systems/Projects

With an objective of managing various diseases and outbreaks across the globe different projects were initiated to collect and analyse data, monitoring and surveillance, and for early detection. Some of the major projects are explained in the following sections. Brief information about these projects is presented in table 2.1.

A. *Argus*

Project Argus is a bio surveillance system designed and developed to identify and track various events that may affect human, plant and animal health across the globe. The project adopts a innovative strategy by monitoring the social disruptions published in local language media

18

reports across the globe. Various media sources including print, electronic, internet and blogs etc. are monitored by analysts who are experts in different local languages across the globe. Bayesian analysis is used for selecting the reports/articles and for initiating alerts. An alert is issued if the analysts come across any event that may trigger an outbreak or that may require further investigation [146].

B. BioCaster

It is a collaborative research project initiated by National Institute of Informatics, Japan, along with five institutes located in three countries for global health surveillance [141]. It is a fully automated system which uses Really Simple Syndication (RSS) feeds from more than 1700 sources, operating mainly in the Asia-Pacific region, posting approximately 90 articles a day [142]. The project is aimed to expand in to other local areas in the region and focused on publishing the articles in all the major local languages in the region. It produces ontology in eight different languages, and is openly available through web-portal, where the maps and graphs related to various health events can be viewed. The ontology covers 117 infectious diseases and six syndromes, with a future objective to expand globally [143].

C. General Public Health Intelligence Network (GPHIN)

GPHIN is a secure internet based early warning system that gathers reports related to public health on a real-time basis, 24 hours a day, 7 days a week. It is a multilingual system developed by Public Health Agency of Canada, and was provided to World Health Organization, international governments and non-governmental organizations [144]. The system monitors various media sources including news wires and websites, where the information is filtered through an automated process and then complemented by human analysis. The output is categorised and forwarded to the users along with any events that may have serious health consequences. It tracks events such as disease outbreaks, infectious diseases, contaminated food and water, bio-terrorism and exposure to chemicals, natural disasters, and issues related to the safety of products, drugs and medical devices [145].

D. Health Emergency Disease Information System (HEDIS)

It is a situation awareness tool developed by the European Commission, based in Italy, and primarily aimed ar crisis management. It supports public health authorities in the member states. There are more than 300 users in Europe who access the system as an inter-

organizational information sharing platform. It is not used for routine bio surveillance, but in case of any outbreak, it accesses the information from other global agencies and makes the information available to its users [147].

Table 2.1 Summary of Systematic review on e-health technologies and disease management.

System Name	Argus	BioCaster	GPHIN	HEDIS
Sponsoring Agency	US	National Institute of Informatics, Japan	Canada	EU
Access	Limited	Open Access	Fee-based	Restricted
Posts per day (approx)	120-170	90	2000	NA
Geographical Coverage	Worldwide	Asia-Pacific	Worldwide	Worldwide
Update Frequency	Every 1-15 minutes	Every Hour	Every 20 minutes	News: Continuous, Documents: when uploaded
Covered Topics	Human, Plants, animals, enviro-dimatic indicators	Human, anumal infectious diseases	Human, Plants, animals diseases; chemical/radiation events; unsafe products; natural disasters	Health threats
Information disseminated	Watch-board and alers	Watch-board	Watch-board, emails to subscribers	Watch-board

2.5. Literature review of Infectious Disease Management Systems

As there are no review studies found using the search strategy for the implementation of e-health technologies for infectious disease management systems in the region of KSA, the studies related to e-health and technologies in other regions are reviewed in this section, along with the e-health applications. This review would help in identifying the technologies and functionalities of the applications used in the management of diseases and healthcare. The outcome of this review would help in identifying the effective and most suitable technologies and functionalities which are currently being used and identifying those which can be integrated into the infectious disease management systems. The study process and the outcomes of the papers are analysed are presented systematically in Table 2..

A systematic review of existing academic literature dealing with classification of the smartphone based healthcare technologies is discussed in the first comparative study [56]. Out of the 83 different healthcare applications reviewed, they were classified in to the following areas, which are the key outcomes of the study: (i) Among the 57 applications used by healthcare professionals, 21 applications are used for disease diagnosis; 6 applications for drug reference, 8 applications for medical calculators, 6 for literature search, 3 for clinical communication, 4 for client applications in Hospital Information Systems (HIS), 2 for medical training, and 7 used for healthcare applications; (ii) 11 applications are categorised for medical and nursing students; (iii) Among the 15 applications used by patients, 6 applications are related to chronic illness, 4 are ENT related, 3 are fall related, and 2 are related to other conditions. The review [56] has covered wide range of aspects including disease diagnosis, training, healthcare delivery, and information management which are effectively managed using information systems technology and mobile technology. The study has found that smartphone technologies are being widely adopted in healthcare and are gaining more attention in the recent years. These technologies are being used for education, remote monitoring, disease management, and healthcare delivery. It has to be noted that web based applications have dual benefits compared to the mobile applications as they can be accessed over mobiles and also on personal computers. Keeping in view of the outcomes of this study it has to be identified that information systems and mobile technologies can be effectively used in the disease management and remote monitoring, which are two major objectives of this research study.

The second comparative study [57] is a systematic review of academic studies with an aim of analysing the impact of e-health technologies in developing countries. In this study, the articles related to different e-health categories are included. The reviewed articles in the study include 15 qualitative studies, 8 descriptive studies, and 32 controlled studies. The results of the study include: (i) e-health technologies improve communication between the institutions; (ii) they can assist in ordering and managing medications; (iii) they can be used in monitoring and detecting the patients who may abandon care show promise; and (iv) use of Personal Digital Assistant (PDA)'s and mobile devices can be effective in quality data collection. The study has concluded that the e-health technologies have a positive impact and can be promising in managing and delivering the healthcare services in the developing countries. It has also identified the need for effective evaluation of the e-health technologies in healthcare sector as the number of new applications and technologies are growing rapidly without proper evaluation, and has identified that the role of e-health technologies would be increasing in the coming years. It is to be noted that one of the main objectives of this research study is not only to develop an infectious disease management system, but also to evaluate its effectiveness and usability; thus adopting a complete development approach which involves testing and reviewing the system.

The third comparative study [58] is a systematic review of mobile healthcare applications, with an insight in to the use of Short Message Service (SMS) for disease control in developing countries. About 98 applications were reviewed in the study, among which 33 were focused on prevention, 19 on surveillance, 29 on disease management, and 17 on patients' compliance applications. The SMS applications were reviewed and evaluated in 31 studies. Most of the studies included were from South Africa, India, and Kenya. The study has concluded that mobile phones are promising tools for disease control, as the healthcare services can be accessed by mobile health applications, in which the costs of healthcare delivery can be greatly reduced in developing countries. In addition, the SMS supported healthcare services can address certain healthcare needs as it is a low cost method of providing services which are effective in implementation in developing countries.

The three studies reviewed [56, 57, 58] in this thesis has identified that internet technologies coupled with mobile technologies can be very effective in disease management, identification, tracking, healthcare delivery, and information and communication management. The major

benefits of these technologies include remote monitoring, effective information management and lowering management costs.

Table 2.2 Summary of Systematic review on e-health technologies and disease management.

No.	Author, Year	Reviewed Studies	Details	Outcome/ Analysis
1	Mosa et al., 2012	55 articles, discussing 83 healthcare applications	57 healthcare applications categorised for healthcare professionals; 11 for medical and nursing students; 15 for patients.	The use of smartphone applications are proving to be effective in managing and delivering healthcare services, and is increasing. The healthcare applications can also be used for educating the patients.
2	Blaya et al., 2010	15 qualitative studies, 8 descriptive studies, and 32 controlled studies	A total of 45 studies have been included mostly from the developing countries, with maximum studies from India, South Africa, and Kenya.	e-health technologies have a positive impact and can be promising in managing and delivering the healthcare services in the developing countries. Need for donors and investors to sponsor outside evaluations so that e-health technologies can be well-targeted.
3	Deglise et al., 2012	123 studies covering 98 healthcare applications.	The 98 applications are categorised under prevention (n=33), surveillance (n=19), disease management (n=29), compliance (n=17), and then accordingly specified these functionalities for different diseases.	Mobile phones are promising tools for disease control, and management. SMS supported healthcare services can address certain healthcare needs and proved to be cost-effective in developing countries.

In addition, to these reviews, three other studies were reviewed, where the platform based (Web/Mobile) analysis is conducted and the summaries of these studies are presented in Table 2.. Out of these three studies, 2 studies are concerned with web-based applications, and 1 study is based on Mobile phone text messaging for disease management. The major points from these three studies can be concluded in the following points:

Clear evidence can be gathered from these randomised controlled studies using mobile phone text messaging intervention and web-based information system as interventions for different healthcare services like surveillance, monitoring, vaccination, data integration and management, treatment, disease control etc., can be beneficial, cost-effective, and effective and efficient in the information and services management.

The use of web-portals for information sharing and integration can be very beneficial, where the information can be viewed effectively with effective tools ensuring high satisfaction levels with the users.

The use of web-based personal healthcare monitor integrated with messaging links and social forums can improve the participation of the users in taking up preventive healthcare measures.

Use of web-based and mobile based healthcare applications can be useful in reducing the healthcare costs, increasing the efficiency of healthcare processes, and engaging the people in different healthcare activities like preventive measures, information sharing, education etc.

Web-based portals can be effective for displaying and analysing the information related to infectious diseases, surveillance, monitoring, identifying outbreak etc. Information can be effectively managed and real time updates can be initiated as the access to the systems can be managed remotely.

These three studies reviewed has identified that web-based platform can be more effective in terms of information access, analysis and display. Additionally web-based applications can be accessed on both personal computers and mobile phones, which ensure remote accessibility with high satisfaction levels.

Table 2.3 Summary of Studies on web-based and mobile based disease management systems.

No.	Author/ Year	Sample Population	Duration	Study Location	Study Design	Disease Type/ Study area	Data Input Methods & Functions	Result	Comments
1	Zurovac et al. 2012	N/A	N/A	Africa	Review	Malaria	Mobile Phone Text Messaging	Text messaging services might improve delivery of health care services and health outcomes in the areas of surveillance, monitoring, pharmaco-vigilance, cost-effective evaluations, information management, and reviews	Mobile phone text messaging interventions can improve the efficiency of healthcare management process and reduce costs.
2	Hu et al. 2007	33 Subjects: BioPortal (N=17), Spreadsheet (N=16)	N/A	USA	RCS	Infectious diseases	Web-based portal	Bio-Portal can enhance public health professionals' surveillance of infectious disease or epidemic outbreak in terms of analysis accuracy and time requirements. High user satisfaction levels.	Web-based portals can be more effective in terms of information sharing, presentation, which can encourage the users to participate

									in the healthcare management.
3	Lau et al. 2014	742 university students: PCHMS (N=370), 6-month wait list (N=372)	6 months	Australia	RCT	Influenza vaccination, health services utilization	Web-based personally controlled health management system (PCHMS)	PCHMS users were 6.7% more likely than the waitlist to receive an influenza vaccine. PCHMS participants were also 11.6% more likely.	PCHMS can significantly increase consumer participation in preventive health activities, such as influenza vaccination.to visit the health service provider.

The next set of review papers focuses on the functionalities/components of the applications used for disease management. Two major aspects were considered, which include Social Networking and Mapping/Surveillance/Monitoring in the process of disease management.

Social Media can be an effective tool in the area of information analytics. They can be used in intelligence research as they have wide scope of reachability and greater access to the people across the globe [134]. Social Networking is being adopted in various areas of healthcare sectors for effective healthcare delivery, education, increasing awareness and disease management etc. Social Networking can be effectively used in healthcare delivery, especially by minimising the healthcare costs in information management. Although there is a risk that false messages can pop-up on the networking platforms, but these are corrected by the officials or other users of the system, and can ensure accuracy. Though social networking cannot replace the existing healthcare system, but if deployed strategically, it can enhance the operative efficiency of the existing systems [135]. They can be used in emergency situations and can be effectively put in to use in early tracking of infectious disease [136]. As they have wide reachability and real time data updating, they can be used as tools for early detection of outbreak or an epidemic [136] and ensures effective management of any outbreak through information sharing and management [137]. The review of these three papers [135, 136, 137] has identified that social networking functionality can enhance the efficiency of current disease management systems and can be used as a tool for early estimation and for studying an outbreak. The summaries of these papers are presented in table 2.3.

The next set of review papers focus on mapping and tracking aspects of disease management systems. Four papers were reviewed, and the summaries are presented in the table 2.3. Though the internet technology systems analyse and provide information about disease and an outbreak, it has to mainly rely on various sources for information: usually through formal channels like government agencies or healthcare organizations; and through informal channels like chat rooms, social networks, press reports etc. As it is always not possible for official agencies to monitor in remote areas or in under developed nations, online platform using internet technologies can be an effective source of information [138].

For an effective analysis of disease related data, mapping can be an effective tool; and the real time mapping through satellite technology offers a detailed view of a disease outbreak through clearly defined pictures using effective data processing methods and temporal Fourier analysis

(TFA) techniques [139]. Another case study [140] shows the effectiveness of an infectious disease surveillance system and enables cross-border visualization, analysis, and sharing of infectious disease information through interactive maps and animation in collaboration with multiple partners via a distributed network. It enables data sharing and users' collaboration in an open and interactive manner. The case study has identified that the disease mapping and monitoring process can be effective using a collaborative approach involving various entities on an online social platform [140]. Though there are existing disease management systems being used, most of them do not include the aspect of social networking. The HealthMap application [61] for example, only collects and integrates outbreak data from a variety of sources, including news media, expert-curated accounts, and validated official alerts, but does not include social Media platforms for information gathering and analysis. However, it can be a good strategy to include social networking as it could enhance the efficiency of existing systems as they can be used for early detection which may not be possible through other sources.

The review of these four papers [138, 139, 140, 61] has identified that various technologies can be used for mapping disease related information including satellite technology, online platforms of official healthcare agencies and non-official sources. It is also identified that social networking could enhance the effectiveness of mapping process through real-time data which can be used for early detection of an outbreak.

Table 2.4 Summary of Studies on Social Networking and Mapping for disease management systems.

No.	Author, Year	Study Design	Disease Type/ Study area	Result	Comments
1	Raina et al., 2011	Perspective	Emergency/ Preparedness	Social Networking if leveraged strategically can enhance the effectiveness of current systems. Social media might well enhance our systems of communication, thereby substantially increasing our ability to prepare for, respond to, and recover from events that threaten the public's health.	Social Networking can be used as a tool to enhance the efficiency and effectiveness of current health information systems.
2	Rumi et al., 2012	Observation/Investigation	Cholera	Social Media and News sources yielded data that is correlated with official data from MSPP. Social media can be cost-effective data source and can be used to complement current methods for early estimation of epidemiological parameters.	Social Networking can enhance the functionality of disease management systems thereby reducing costs and can be used for early estimation of health related parameters.
3	Jennifer et al., 2011	Epidemiologic Investigation	Tuberculosis	Social Networking can be used to identify the source patient in the event of an outbreak, and can help in studying the outbreak.	Social Networking can be used as a tool for analysing and investigating an outbreak of a disease.

4	John et al., 2009	Investigative	NA	The Internet based systems provide a powerful communications channel, but it is health care professionals and the public who will best determine how to use this channel for surveillance, prevention, and control of emerging diseases.	These Internet-based systems are quickly becoming dominant sources of information on emerging diseases, though their effects on public health measures remain uncertain
5	Hay et al., 2006	Investigative	NA	Satellite technology can be very useful in mapping disease related information.	This process enhances speedy updation and ensures early warning system.
6	Gao et al., 2008	Case study	Infectious Diseases	Development of standard health services and spatial data infrastructure can enhance the efficiency and effectiveness of public health surveillance.	Effective Information Systems can enhance the public health surveillance process, and sharing disease information through Geographic Information System (GIS).
7	Freifeld ., 2008	Investigative Report		HealthMap application is a useful free and open resource employing text-processing algorithms to identify important disease outbreak information through a user-friendly interface.	Though it is effective to an extent, it does not incorporate social networking functionality.

2.6. Applications for Infectious Disease Management

There are various applications developed for managing different infectious diseases, which have different functionalities. The efficiency and usefulness of these applications can be measured according different features they come along with and also using some performance indicators like usability, navigation, multi-language support, visibility, speed, information availability etc. In this section, some major healthcare applications are analysed according to their different features, as shown in Table 2..

Table 2.4 Summary of the key functions and characteristics of some major healthcare applications.

Apps Name/ Features	Health map [61]	eDEHN [60]	HEALTHY.ME [62]	Infectious Diseases Compendium [63]	Bio portal [59]
Web based or mobile app	Web-based	Web-based	Web-based	Mobile app	Web-based
Social networking	NO	NO	YES	NO	NO
Education	YES	YES	YES	YES	YES
GIS	YES	NO	NO	NO	YES
Alerts	YES	YES	YES	NO	YES
Trend chart	NO	NO	NO	NO	YES
logbook view	YES	YES	YES	YES	YES
Map	NO	NO	NO	NO	YES
Booking appointment	NO	YES	YES	YES	NO

Coaching and Behavioural Change	NO	NO	NO	NO	NO
Documents	YES	YES	YES	YES	YES

Five major Healthcare applications for disease management were reviewed, out of which four of them work on web-based platform and only one application works on mobile platform. The functionalities of these applications are shown in table 2.4. The major components of this research study including social networking and mapping for infectious diseases were not found among all these applications except Healthy.me (includes social networking functionality), and Bio Portal (includes Map view functionality). All the applications reviewed provide educational activities, documents and logbook view functionality. However all the applications lack few important functions like coaching and behavioural change functions, trend chart functions etc. Most of the reviewed applications lack features which can be useful for information sharing like Social networking, messaging features, and also the features to upload and analyse the change and behavioural patterns of the users. Few applications are in specific to healthcare professionals, while few applications can be used by all the shareholders including patients, healthcare providers, and medical students and nursing staff. Social Networking and Mapping are two major functionalities together, which are not identified among these applications.

2.7. Infectious Disease Management Systems in the Gulf Region: The Current Status and Potential Impact

2.7.1. Introduction
The research works carried out in the Gulf region on using e-health systems in the context of managing infectious diseases are reviewed in this section. A systematic and an extensive review is carried out for identifying the existing publications in this area.

2.7.2. Methods
The extensively reviewed articles available in the different electronic medical databases are identified and filtered to find the studies related to this research study (Infectious Disease Management Systems). Both English databases including PubMed, IEEE Xplorer, Web of Science, and Arabic databases including Al Manhal, Mandumah, AskZad are used to identify the related studies. Different key words are used in the process of searching which formed as the

mixture of expressions of different aspects related to this research study. The key words like "infectious diseases", "e-health", "infectious diseases management systems" are used along with the name of the region to limit the scope of the results to the specific area of using e-health technologies in infectious disease management. In order to streamline the results to a specific area, the region name is specified in the search terms, for example. "Infectious diseases management systems and Saudi Arabia".

The following criteria is used in the selection of related studies from the electronic databases: a) If the studies used e-health systems as the major intervention tool for the self-management of infectious diseases, b) if the study either used a quasi-randomised trial, or limited trial, or trial managed before and after the study, or a randomised controlled trial, c) only those articles dated between 1990 and 2014, d) those articles published in English and Arabic languages, e) only peer reviewed studies or publications or peer reviewed proceedings of international conferences. Hand Search, i.e., few paper print articles and studies were reviewed personally in libraries. In addition, the following exclusion criterion is used for excluding the unrelated studies: a) if the reviews of the study are not based on the original data findings, b) if the articles were unrelated to the infectious disease management c) if the articles are only reports were the details of the study is not explained d) duplicate or overlapping publications, e) if the articles are only centred around clinical professionals and avoiding the focus on the patient's side.

Apart from these inclusion and exclusion criterions, other aspects were also considered in identifying the studies related to this research study. These other aspects included the factors like design of the study; application devices used in the study; the study participants which includes patients or individuals, families, and study controllers like healthcare service providers; the type of data collected; targeted population; data collection and analysis techniques; data analysis techniques in specific to factors like acceptability, feasibility, efficiency of the system and effectiveness of the study; exploration outcomes; and majorly the outcome of the study, i.e. experimental results, and review if presented. Figure 2.4 presents the strategy adopted in searching and filtering the existing studies similar and useful to this research study.

```
┌─────────────────────────────────┐
│ 96 English articles identified  │
│  20  pubMed                     │
│  6   web of science             │
│ 63 IEEE                         │
│  7   hand search                │
│                                 │
│ 68 Arabic articles identified   │
│ 66  Al Manhal                   │
│  0   Mandumah                   │
│  2  AskZad                      │
└─────────────────────────────────┘
             │
             │        ┌──────────────────────────────────────────────────┐
             │───────▶│ 152 excluded                                     │
             │        │ 137 unrelated to Infectious Diseases Management   │
             │        │ Systems                                          │
             │        │ 9    duplicate or overlapping publications        │
             │        │ 2    reviews                                     │
             │        │ 4  others*                                       │
             ▼        └──────────────────────────────────────────────────┘
┌─────────────────────────────────┐
│ 12 full-text articles reviewed  │
└─────────────────────────────────┘
             │
             │        ┌──────────────────────────────────────────────────┐
             │───────▶│ 12 excluded                                      │
             │        │                                                  │
             │        │ 12 did not meet inclusion criteria               │
             ▼        └──────────────────────────────────────────────────┘
┌─────────────────────────────────┐
│                                 │
│ No studies                      │
│                                 │
└─────────────────────────────────┘
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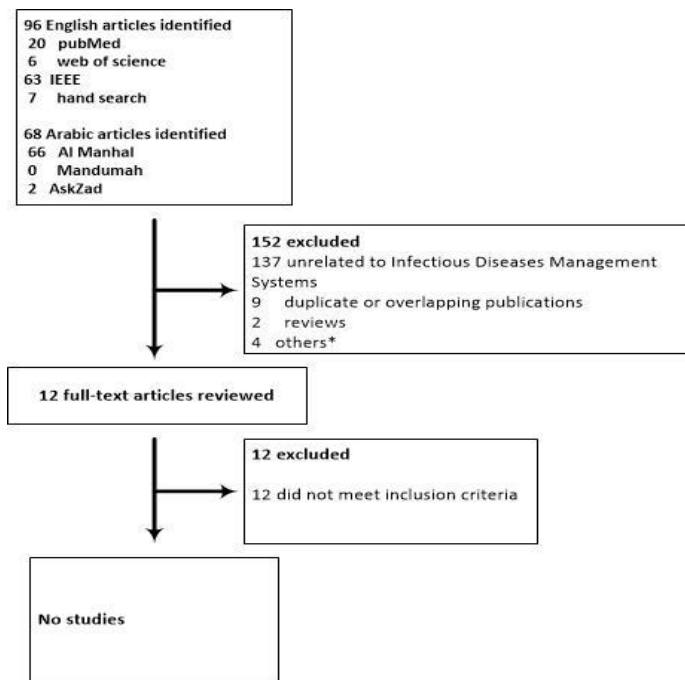
Figure 2.4 The Search Strategy.

2.7.3. Results

96 English articles and 68 Arabic articles were identified in the first stage of selection process. Out of the 96 English articles, 20 articles were identified from PubMed, 6 articled were identified from web of science, 63 articles were identified from IEEE Xplorer, and 7 articles were identified through hand search. Out of the 68 Arabic articles, 66 articles were identified from Al Manhal, 2 articles were identified from AskZad, and no articles could be identified on Mandumah. In the second stage of selection process, 152 articles were excluded. Among these, 137 articles were excluded because they were unrelated to infectious disease management systems, 9 articles were excluded because they were duplicate or overlapping publications, 2 articles were excluded because of the reviews did not satisfy the selection criteria, and 4 articles were excluded because they did not satisfy the other aspects included in the selection process. The remaining 12 articles were identified and reviewed. These 12 articles were excluded in the next stage of selection process because they did not satisfy the inclusion criteria. Out of these 12 excluded articles, 6 articles were excluded because their reviews are only based on e-health technologies, and did not focus on the concept of infectious disease management and the other 6 articles were excluded because they were only reports in which the details of the study is not presented.

There is no evidence of trials or studies conducted with respect to the infectious disease management Systems in the Gulf region and in specific to the Kingdom of Saudi Arabia. Therefore, this aspect of using e-health systems with the focus on the citizen centric approach is a completely new concept of healthcare management for infectious diseases in the region of KSA.

This review process has been adopted to identify the potential studies that could be useful in identifying the past and existing data related to the infectious disease management in the region of KSA. But, the end result of the search strategy has found no such studies, and it reflects the potential area for research which could contribute major findings and possibilities for implementing the advanced and effective e-health technologies in managing infectious diseases in the region.

2.8. Social Networking for Healthcare

Social networking features are being increasingly adopted across healthcare services in various aspects. It is evident from increasing healthcare applications for various health related services and disease management. About 72% of the people affected with chronic diseases in USA are using such technology for their disease management [64]. Social Networking is also becoming increasingly popular in the Kingdom of Saudi Arabia, with WhatsApp on the top of the list with 27% penetration rate followed by Facebook (25%), Twitter (20%), and Skype (14%) [81]. This section explains the general social networking architecture and some popular social networking systems used in healthcare management and services, and analyse the importance of social networking for IDM.

2.8.1. General Architecture of Social Networking

Social networking has been defined in many ways by different authors. A social network is considered to be a common platform, where social relations are built among the people who share common interests. In the context of social sciences it can be understood as the social structure consisting of group of actors which might include individuals, groups or organizations with dyadic ties between them [65]. The general social networking architecture is presented in Figure 2.5. The basic features include the following:
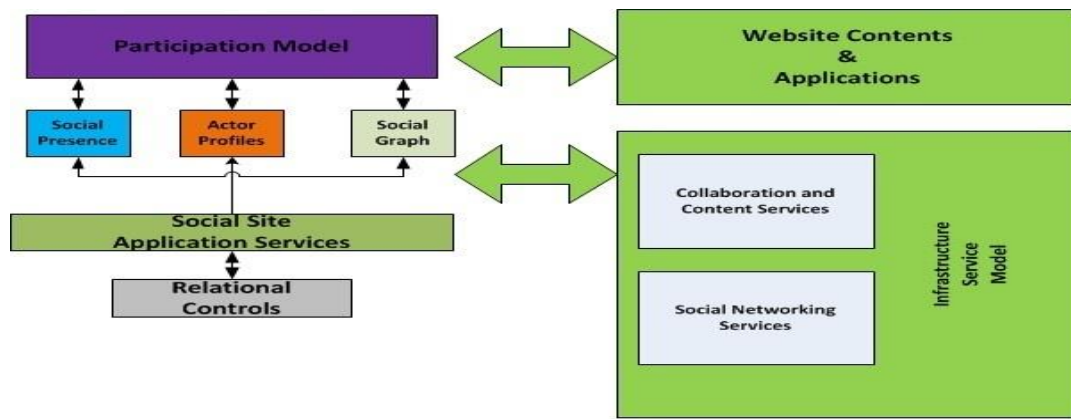
Figure 2.5 General Social Networking Architecture [66].

A 'social networking graph' is used for representing and implementing the social network [67].

The actor profiles in the social network are termed as 'user profiles'.

A new term 'social presence' is coined in the social networking recently, which explains the availability or the presence of the actors on the network. Previously the term used to showcase availability, or being connected, or online. However, these days it is updated, which is notified by the 'current status', with a description stating the actor's activity in real time.

There are different tools such as instant messaging, message board, dash boards which are used as the tools for communicating and interacting among the users, and are referred as 'User participation tools'.

The types of relationship among the actors are defined by 'Relation controls' [66,67].

2.8.2. Social Networking Types for Healthcare

Social network in healthcare can be classified with respect to the type of users.   Figure 2.6, represents the three types of social networking that can be used in healthcare management.
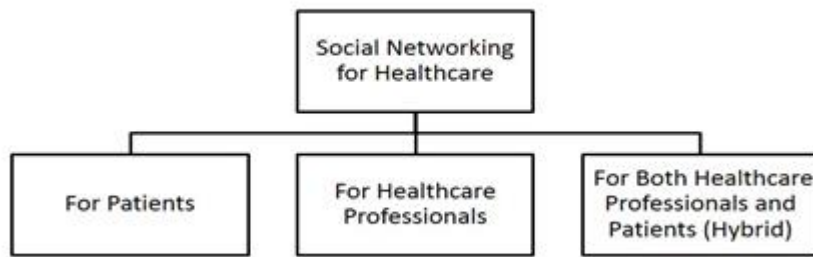
Figure 2.6 Social Networking Types for Healthcare.

Social Networking for Patients

The patients are the key participants in this type of social networking platform. The social graph in this type includes only patients and the relationships between them. Hence only patients can participate in communication and interaction on this platform, with no access to other actors. 'PatientsLikeMe' is an example of such social networking platform [68]. This type of social networking benefits the patients as they interact with other patients facing similar conditions and treatments, where they can openly share their feelings and provide support to each other. As it is not always possible for the patients to visit support groups, this type of social platform can be reliable and very useful in having friendly discussion, support and information sharing.

Social Networking for Healthcare Professionals

Healthcare professionals are the key participants in this type of social networking platform. The social graph in this type includes only healthcare professionals and the relationships between them. Hence this type of social networking platform is only dedicated to healthcare professionals, where they can share useful information with other participants. Various research updates can be shared among the participants, and can such platforms are very useful for knowledge sharing. Additionally, with no geographical boundaries, the professionals can share information regarding different cases, treatments, methods and practices at various locations [69]. 'sermo.com' is an example of such social networking platform.

Hybrid Social Networking for both Healthcare Professionals and Patients

Both healthcare professionals and patients are the key participants in this type of social networking platform. The social graph includes both healthcare professionals and the

relationships between the patient to patient, healthcare professional to healthcare professional and patient to healthcare professionals and vice versa. This type of social networking effectively supports healthcare management as different information such as follow-up, test results, consultation, feedback, and reviews can be shared among the users. Additionally, it helps in real time information sharing and can be useful for information sharing among the patients who are in remote locations and doesn't have clinical facilities. 'Tudiabetes.org' is an example of this type of social networking platform [70].

Social Networking Applications for IDM

Various social networking applications for IDM are reviewed in this section. The applications to be reviewed are categorised in to the following sections.

- Public social networking platform, which can be used by everyone and can also be used by patients with infectious diseases.
- A general social networking platform, which is specifically designed and developed for healthcare services, and can also be used by patients with various infectious diseases.
- A private social networking platform, which is specifically designed and developed for IDM, and can be used by patients with various infectious diseases.

Facebook is reviewed as the public social networking platform. There are various benefits of Facebook, as users can share information through various means. Users can post messages of some important information on their walls which can be viewed by other users. Messaging features can be used for sending personal messages, which can't be viewed by everyone except the user to which the message is transmitted. Facebook also allows the users to launch applications on its platform, which makes it more functional and can be used for specific streamlined purposes. The security features also provide different settings which users can use in order to maintain their levels of privacy [71]. Additionally, the calendar feature it provides can be very useful for reminders and planning. Facebook can also be integrated with other mobile applications which ensure multiple levels of information access, and helps in interactive information exchange. Specific groups can be created on Facebook, where the users with common interests can participate. Companies or Organizations can also launch their institution specific pages, which can be followed by the people and can have up to date information in different fields [72]. Infectious Disease Society of America, Infectious Disease Institute are few pages which can be found on Facebook.

Twitter is another public social networking platform just like Facebook, but the modes of communication are different from that of Facebook. Twitter allows its users to send short messages, which are usually called as tweets. Tweets can be posted online through web interface or by SMS on mobile, or by using twitter application on mobiles. Most of the conversation on the twitter usually happens within few hours after posting the tweet, which is more like a real time communication for short period [73]. Whereas in Facebook the communication is on-going, and can go on for longer period. To follow some important discussions or a topic, twitter can be used as users can pinpoint their point of interests.

People with different infectious disease can follow disease specific pages or general infectious disease portals to increase their knowledge and awareness on both Facebook and Twitter. For example users can follow @TBAlliance on twitter to increase their knowledge and understanding of Tuberculosis, or can follow @infdisease_news to increase their understanding of infectious diseases and to be up to date with latest information on twitter. Similarly, users can follow different healthcare organizations which are disease specific or healthcare specific and increase their awareness. Additionally they can also participate in conversations by posting messages or tweets, and increase their social presence which could foster their self-management approach.

PatientsLikeMe is the one of the popular social networking application in the field of healthcare which allows users to understand disease symptoms, examine their medical conditions and review their condition [68]. The application supports 16 health related issues and supports patients emotionally by acting as a motivational technique [74]. The application allows users to share their views and experiences and also their recommendations which can be viewed by other users. It also allows the users to view their health related data over a period of time while under treatment or medical drugs graphically which ensures the effective analysis of the patient's improvement or medical condition. The application is integrated with online tracking and clinical trials. The patients who are interested can participate in clinical trials and provide their health related data and feedbacks along with the response to drugs. This approach ensure in having a large database with different health related information, which can help in research and better understanding of various complications and medical conditions. It also benefits pharmaceutical companies, research laboratories, and educational institutions in inventing better approaches and cures to the various diseases [74-76].

CureTogether is another social networking application in healthcare which provides the basic services which include information sharing and emotional support [77]. The users of the application can share their information and can track their medical condition while highlighting the main cause which is emotional support [78]. The application allows the users to enter their medical condition which usually includes the information like symptoms, treatment, medication, cure, improvement etc., and can review their progress using rich graphical tools for better analysis. Additionally, the application also allows the users to view their medical details in analytical mode [74].

MedHelp is another popular social networking application in the field of healthcare, which interconnects patients and healthcare professionals, ensuring the delivery of medical advice and support. The patients can communicate with healthcare experts about their condition and receive feedback on the information they have provided. The application allows the users to manage their medical condition more effectively as they can directly discuss with healthcare experts [79, 90].

One of the most popular wireless mobile social networking system in the field of healthcare 'mCare' has many features which would help in better management of healthcare services [67]. There are different features which ensure information readiness, knowledge improvement, and information sharing. The system allows the users to share their questions or doubts and also the answers (if they knew) with their friends and physicians. The users can recommend physicians to their friends. Users can also categorise their questions as favourites and can view them anytime, and have the ability to access their Google Health records [67].

There are both general and disease specific social networking applications are available in the market. These applications offer information to the users in order to increase their knowledge and understanding of a medical condition, and also provides support by advising on precautionary and preventive methods [70, 81]. Patients who use these applications would be effective in managing their medical condition better than those who do not use such applications. These applications also ensure better healthcare services by reducing costs to a great extent. Apart from these applications, other options like individual blogs, diaries, and Wikis are also being used in order to gain information regarding nutrition, diet, medical conditions, symptoms, preventive measures etc.

From the above discussion, it can be concluded that social networking can be used as a tool to improve healthcare services but cannot completely replace physicians or clinicians. They are best used for information sharing, knowledge sharing, receiving feedback and advices. They are most useful for people in remote locations where they do not have any access to healthcare services, as they can receive advice and treatment over the application. Furthermore, there were no previous studies found which dealt with IDM integrating social networking for Saudi patients. This area largely remained unexplored in Saudi Arabia, where there is an increasing trend in adopting internet and web technologies, with a high risk of infectious diseases. Table 2.5 compares some of the social networking platforms and their features.

Table 2.5 Summary Analysing of Social Networking Applications for Infectious Disease Management.

Social Networking System	Social Networking Graph	User Profiles	User Social Presence	User Participation Tools	User Relation Controls	Infectious Disease ManagementTools
Facebook	Many	Many	Current status	Private messaging Instant messaging and other	Friendship	Participation tools are used for managing the patients' medical condition such as patients can update their status using this tool or share information on their wall
PatientsLikeMe	Patients	Patients	Current status	Private messaging Forum Instant messaging	Follow me	Patients can use the application to store the health related data, and can view their historical data using GUI tools.
mCare	Patients & Doctor	Patients & Doctor	Current status	Private messaging Ask Doctor	Friendship	N/A

2.8.3. Potential Effects of Social Networking for Infectious Disease Management

As explained in the previous sections, social networking can be used as a tool in effective management of infectious diseases by using its features like information and knowledge sharing, emotional and motivational support, advice and treatment etc. However, there was no study found which addresses the impact of social networking in specific to IDM. From the literature reviewed, the benefits of social networking in IDM can be summarized in the following points.

Health Behavioural changes among the patients: Social networking can be used as an approach for achieving the behavioural changes in the people by increasing their knowledge and awareness, and preventive and precautionary methods about the various infectious diseases. It can be used as an education tool and also as a platform to exchange ideas and experiences. There are many social networking applications which are being used in this aspect. For example AAFP (American Academy of Family Physicians) has a Facebook page, and provides an open discussion for people with various medical conditions [82]. Accessibility, convenience and 24x7 support offered by the AAFP helps the patients to access information and undergo behavioural change according to the advice or suggestions made on the social networking platform.

Improved interaction between physicians and patients: The social networking platform allows the patients to interact with physicians in a more effective way, overcoming the drawbacks of traditional clinical visits. It helps in reducing the healthcare costs and also helps the patients remotely access the healthcare services without being required to visit the clinics. Effective utilization of healthcare resources: The use of social networking platform ensures the effective utilization of healthcare resources. As most of the diagnosis or advice is being given online; this would reduce clinical visits as patients would require clinical visits only in an emergency. Therefore, the use of healthcare resources can be minimised and streamlined according to the needs, ensuring the cost cuttings.

Effective feedback and communication: As the overall communication is one to one most of the times, the relationship between the patients and physicians would be improved and better analysis of the patients' condition can be achieved which would ensure better feedback. Additionally, the information can be used by the research organizations and medical

institutes to understand the medical conditions of the affected people in a more effective way, which would help them in finding better cures [76].

2.9. Conclusion

In this chapter, an overview of infectious diseases, challenges, and their management is presented in the general and Saudi Arabia context. Previous works and literature related to IDM are reviewed and analysed. The role of information system technologies and mobile applications in IDM is presented. The role of social networking in IDM along with its benefits is also discussed in this chapter. The key outcomes of this chapter are explained in the following points.

The papers and literature reviewed in this chapter shows a clear evidence of significant improvements that can be achieved in IDM and self-management by using disease management applications/ systems.

The information regarding the IDM in Saudi Arabia is very limited and very few studies are found in this aspect related to the region. Therefore there is an immediate need to explore the IDM in Saudi Arabia and also to increase the research studies focusing on the design, development and implementation of web technologies for IDM in the region. The aspect of self-management and the use of social networking tools in IDM in the country also need further research to identify the possibilities of implementation for providing better healthcare.

No previous studies were found in the region which dealt with integrating web IDM and social networking interventions. As this technology is new, and not many research studies were found in other regions, there is a need for in depth research in this aspect. Though there are disease specific web applications found, there are no applications found integrating social networking with infectious disease management tailored according to the needs and requirements of the physicians and patients in Saudi Arabia.

An increasing trend of internet and mobile usage is observed in Saudi Arabia especially among the educated and younger population. Taking it as an opportunity and advantage there is a need for formulating innovative and effective healthcare strategies in the country for promoting web technologies especially in managing infectious diseases, which can prove to be beneficial in many circumstances.

In the next chapter, we will provide an introduction about the proposed infectious diseases management framework for Saudi Arabia (SAIF).

Chapter 3: Infectious Diseases Management Framework for Saudi Arabia (SAIF)

3.1. Introduction

The spread of infectious diseases in the modern global world requires new infectious diseases management systems. The impact and the speed of infection spreading and the potential for outbreaks have increased particularly in the last few years. These outbreaks can affect human population on an unprecedented scale and across many geographical locations. However, modern technological advances particularly in information and communication technology can assist in devising new infectious diseases management solutions.

In the previous chapters, a review of a number of techniques and approaches, particularly in the context of the Kingdom of Saudi Arabia, has identified the many challenges and problems being faced by the KSA in the management of infectious diseases. Thus, there is an urgent need for innovative strategies for the KSA to manage infectious diseases, and to deliver healthcare services and medical education not only to infectious diseases patients but also to exposed or vulnerable people. In fact, to date, there has not been a comprehensive study conducted on the development, impact and evaluation of infectious diseases management systems in the KSA.

The modern management of infectious diseases requires in-depth exploration of the latest techniques and technologies, particularly the use of smart and effective web management tools, to address the serious problems and challenges in infectious diseases management. This should include the provisioning of emotional support and health education using social networking concepts. Thus, the aim of this chapter is to develop an Infectious Diseases Management Framework for Saudi Arabia (SAIF) that uses an effective web-based information system containing social networking and mapping features, and which is tailored according to the healthcare needs.

This chapter explains the series of concepts used for building the SAIF framework, which include requirement analysis and the processes deployed for gathering the requirements, the architectural design of SAIF and the deployment tools to be used. In fact, requirement analysis and the proposed architecture and design are two key stages in the

development of SAIF. These stages of SAIF concentrate on how the system's modules, entities, operations and technologies are chosen in order to produce a working system that meet not only functional requirements but also non-functional quality requirements. Thus, activities such as gathering and comprehending SAIF requirements and producing design diagrams for the various modules and operations are conducted before the implementation and evaluation.

3.2. Development Methodology

The SAIF framework development, deployment and evaluation lend itself to software development lifecycle which typically includes different phases such as requirements gathering and analysis, planning, design, development, implementation, testing and evaluation. The software development method for SAIF should be simple, easy to implement, and is adaptable to the changes during and after the system's development. The waterfall method with its top down methodology is well suited for the project as it meets the chosen requirements, and it is adopted for developing the SAIF System.

The waterfall method includes a series of sequential stages, where each stage is designed to carry out the necessary tasks before proceeding to the next stage of development [84]. Each stage is carefully assessed and reviewed before continuing to the next stage. This ensures the system's quality with continuous risk assessment and management in the system development process. Clear estimates, deadlines and milestones are devised for each task in the process, which allows the developers to keep control of cost and time.
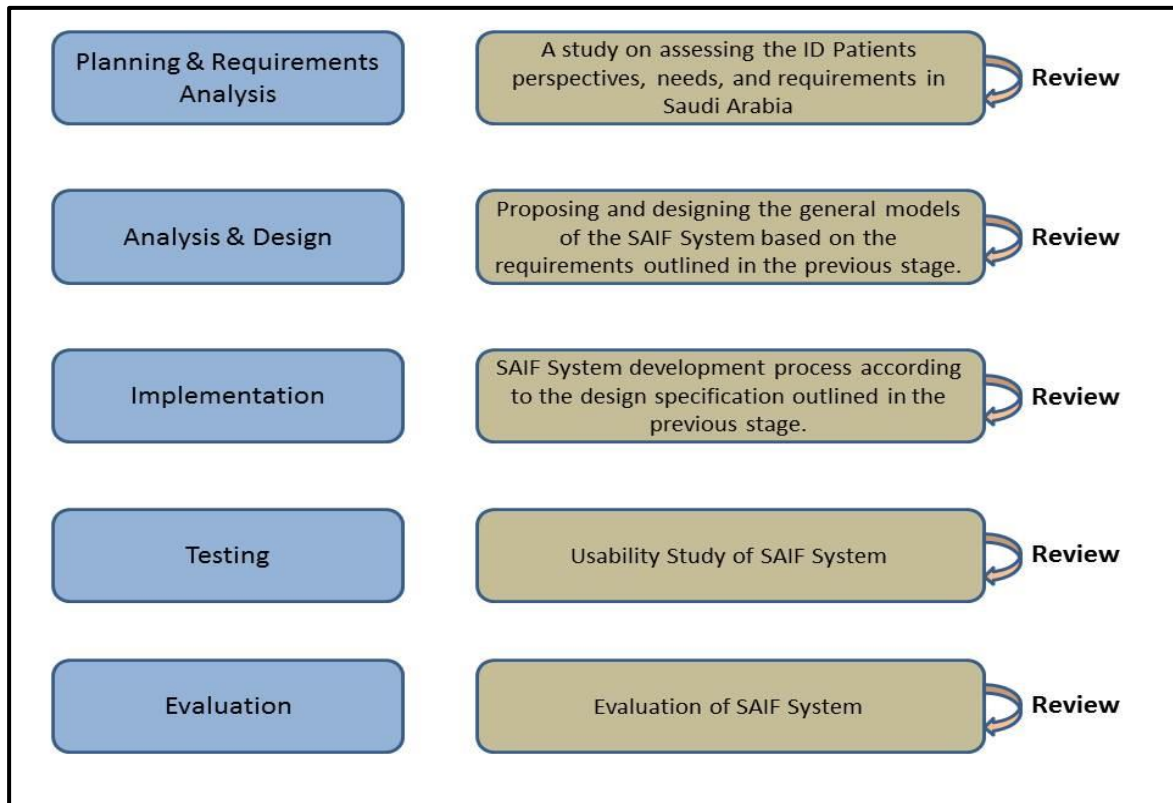
Figure 3.1 SAIF Development Method.

The waterfall method is well suited for use in the development of a SAIF system as there is no risk of frequent changes during the development process. The method includes a series of stages such as planning and requirements analysis, analysis and design, implementation, testing and evaluation. These concepts are embedded in to the research developmental work, which is represented using the SAIF development method, as shown in   Figure 3., and they are defined as follows:

Planning and Requirements Analysis: The activities carried out in this development stage include:

- Background study: Conducting a background study is the first and one of the most essential steps to developing any new systems. A comprehensive background study into infectious disease managements was performed in the literature review chapter (chapters 2).

- Requirements gathering and analysis which includes questionnaires and interview with different types of users are quantitatively analysed.

- Requirement specification.

Design and Architecture: The activities carried out in this development stage include:

- Translating captured users' requirements and specification into design using a number of UML (Unified Modeling Language) diagrams.

- Producing use case diagrams.

- Design of the system architecture and functionalities diagrams.

- Design deployment diagram showing the potential technologies including hardware and software tools.

- Design of graphical user interface (GUI) prototypes to be used in the implementation stage.

Construction and Implementation: All the major construction and implementation activities take place at this stage. The activities performed at this stage are coding and constructing the modules which are tested separately. This is done over a number of incremental iterations driven by testing and addressing any changes that are needed to the modules. This stage also includes system integration of the separately tested modules.

Testing: Although units and modules testing take place in previous stage, full integrated system testing takes place at this stage. Any system defects are identified and addressed at this point. Due to the nature of the project and aspects of privacy and, trust and security checking should be performed vigorously. This stage also includes the evaluation of the usability of the developed system.

Evaluation: This is the final stage of the SAIF framework with a case study based evaluation.

Although the waterfall methodology is used for the development of the SAIF system it is notable from the above that some aspects such as the modularisation, i.e. developing testing individual modules (components) reflecting the main functionalities (functional requirements) of the system was adapted from the Rapid Application Development Model – RAD [85] with other stages similar to the waterfall model such as requirements analysis and planning stage, design stage, the implementation and testing stages (see Figure 3.2).
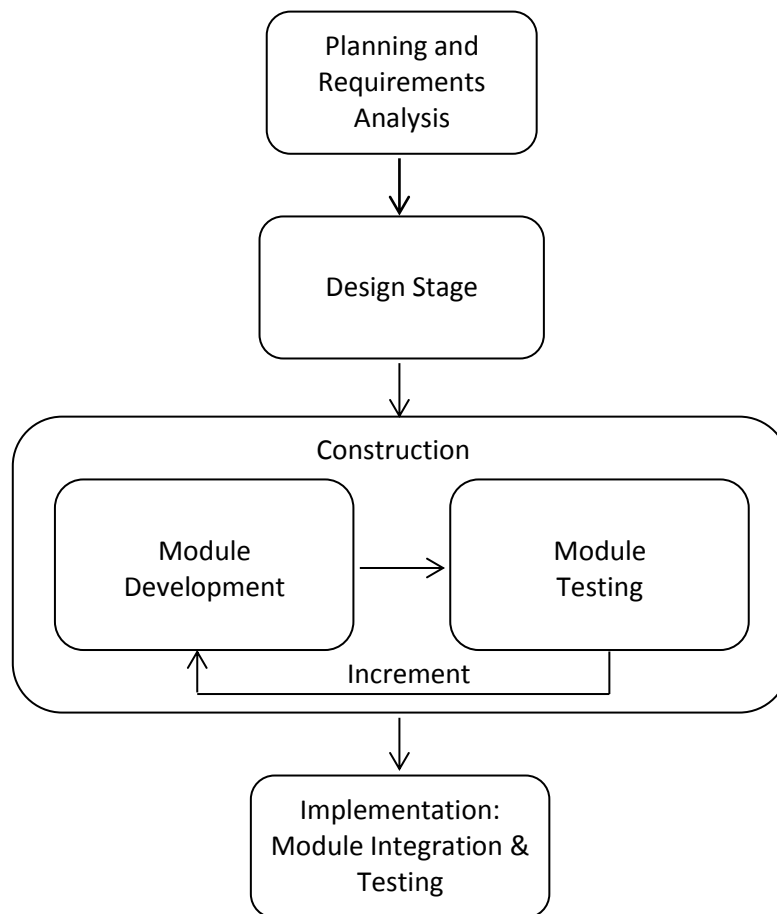
Figure 3.2 The RAD Model.

In summary, this development combination was chosen because of three main reasons:

- Its incremental approach to software development;
- It is an appropriate development method for use in this project, and;
- The functions of SAIF system can be modularised and tested before full integration testing which saves on development time.

After analysing the new technologies, functionalities, and applications; and their impact on the infectious disease management (IDM); the current situation of infectious disease management in Saudi Arabia; and need for developing an IDM System in Saudi Arabia, and various other related literature sources in chapter 2, the next major step is to gather the needs and requirements of the users of IDM in Saudi Arabia, based on which the SAIF IDM System

can be designed and developed. The process of requirements gathering is explained in the next section.

3.3. Requirements Gathering & System Analysis

System analysis is the first stage of the software development and it involves gathering information from all potential stakeholders in order to identify user/system requirements. It is very important to get the right requirements and to produce specifications that correspond to the projects elements. Any ambiguities at this stage can lead to serious defects and might have severe impact on the whole project, and which can be very costly to address if discovered at the later stages of the project development lifecycle. In the following subsections the different system analysis activities for the development of SAIF are presented including a quantitative analysis of users' requirements.

3.3.1. Requirement Analysis

As mentioned above requirements analysis is an essential stage in the software development lifecycle. In fact the whole system development, including design and coding, is based on requirement analysis. It is also important for the evaluation and testing stages as it is used to validate the main functionalities of the system and whether they have been met. Thus, considering the importance of this stage all elements of ambiguities and potential conflicts should be removed or minimised.

Like any software systems SAIF's requirements are classified into functional and non-functional requirements. Functional requirements defines the system intended use and its operations and services. Non-functional requirements on the other hand represent its quality i.e. how well does the system operate and perform its functions/operations, and include quality factors such as reliability, usability, security, availability, maintainability etc. Non-functional requirements are important, for example a system can function but with poor usability. Before outlining the functional and non-functional requirements, a survey based study and structured interviews are conducted to identify and collect the needs and requirements of all the stakeholders of the SAIF system in Saudi Arabia. The details of the process are explained in the next section.

3.4. Requirements Gathering & Quantitative Analysis

This preliminary study for requirement gathering was carried out in two phases. Firstly, in order to understand the need for smart and effective web management tools for infectious diseases management (IDM), a series of interviews were conducted with 3 senior clinicians specialised in infectious diseases, 4 healthcare staff, 4 healthcare providers and 2 policy makers and advisers to the ministry of health in the KSA.

Secondly, in order to identify and analyse the major web elements and features to be used in the SAIF, a follow-up survey questionnaire was designed and completed by 67 patients suffering from different infectious diseases. These patients were recruited by the clinical staff during the patients' clinical visit i.e. personally, and then follow-up was conducted electronically through emails.

The survey questionnaire (shown in the appendix B) used an unstructured format, and included questions relating to the need for smart and effective web management tools for IDM systems, along with the requirements and concerns raised by the clinicians, healthcare staff and authorities. As there were no KSA related studies found in the systematic review, the survey questionnaire was designed by considering the studies explaining the use of effective web elements and modern information technology features in disease management systems. The series of interviews conducted with Specialised Physicians, healthcare staff, and Policy makers have identified various areas which need special attention and necessary to be considered in developing an effective IDM. The major points that can be outlined from the interview process include the following:

- Managing infectious diseases is a complex task as it includes many symptoms some of which might be shared among different infections.
- Information about infections, guidelines and infection avoidance advice should be publically available.
- Infections descriptions including symptoms should be included to offer some assistance to medical professionals.
- Mapping of infections spreading particularly in the case of outbreaks should also be included.

- Information about patients is important to understand for example their medical history, and to help in the identification of vulnerable people such the elderly and the seriously ills.

- All the interviewees expressed strong support for the use of social networking through a web-based platform for information sharing in SAIF, with a focus on enhanced self-management elements.

- Privacy and confidentiality measures should be included.

- The extent of sharing personal information over the website module in the SAIF system must be limited.

- Specific alert/reminder functionalities are necessary which should alert the patients through an SMS or email, or through an alert message on the system.

- There should be provision for asking questions of the healthcare specialists, authorities and clinical staff, and sharing educational resources.

- A pilot study is essential to understand the use of the infectious diseases management system developed using SAIF architecture, and it must be evaluated.

- A simple mechanism must be designed for interactions between patients and clinicians.

- The system should be simple and easy to use.

The second phase of study for requirements gathering includes survey process. The survey is mainly focused on identifying the needs of the general users of the SAIF System, including patients and general public. The survey questionnaire covered wide range of aspects relating to the functioning of IDM System, and the survey responses received can for the basis for outlining the functional and non-functional requirements for the SAIF System.

The responses from the survey (see Appendix B for questions list) reinforce the idea of using social networking for IDM and information sharing on the web portal for IDM. Figure 3.3 and Figure 3.4 give an overview of the demographic information of the survey participants. Out of the total participants (n=67), the majority of the participants were male (n=44, 65.7%) which might be explained by the male dominance in public life (see

Figure 3.3). In addition the majority of participants were aged between 18-40 years (n=37, 55.2%) reflecting the large young population of the KSA

(see   Figure 3.4) and almost all the participants visited
the clinic for their infectious disease treatment and check-up.
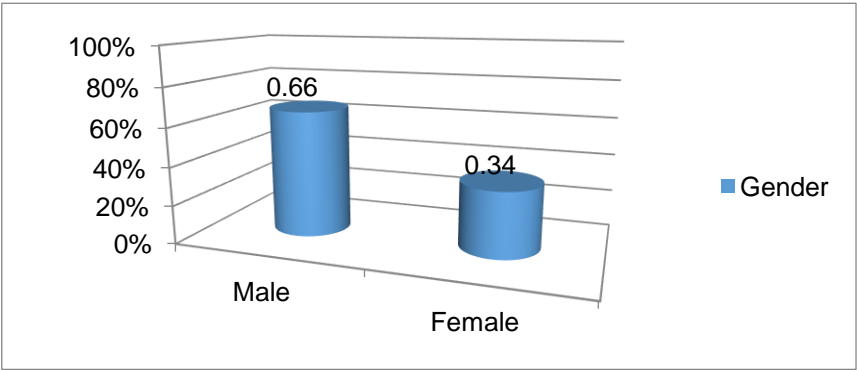
Figure 3.3 Gender.
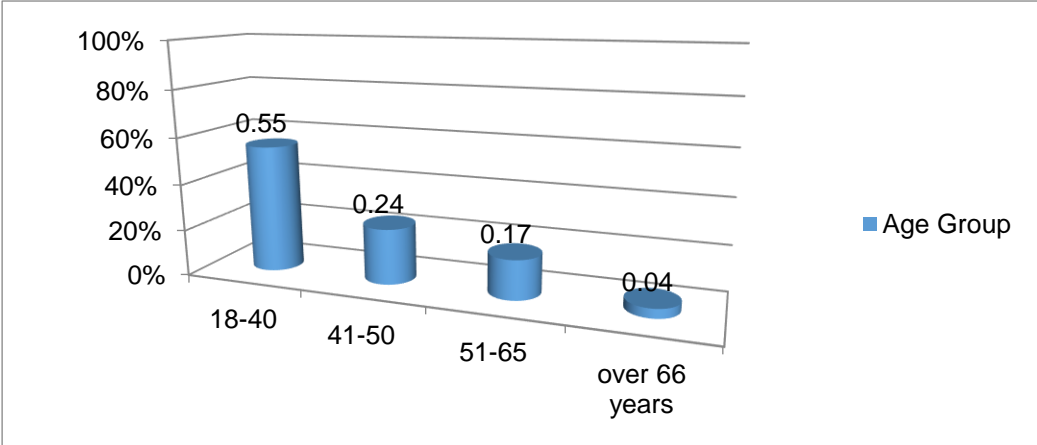
Figure 3.4 Age Group.

The first part of the survey was concerned with the participants' current use of internet
technologies, which includes emails, social networks, news, and specific use such as online
shopping and the use of the web to enquire about health issues (see Figures 3.5 –3.8).
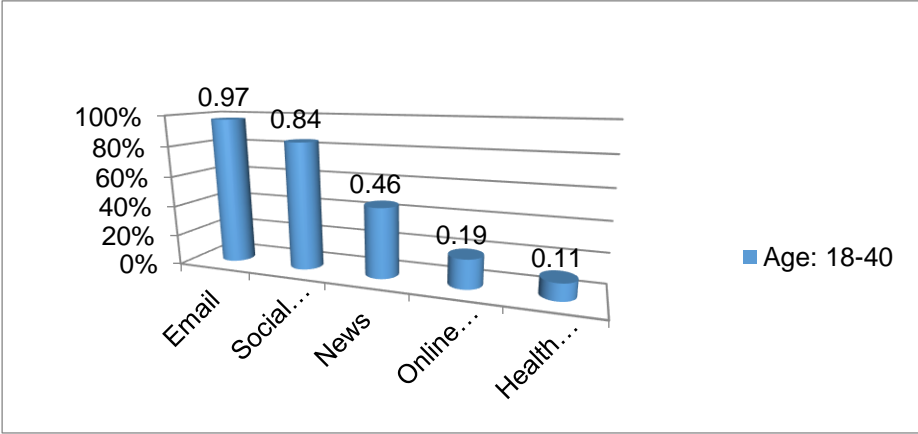
Figure 3.5 Web usage age 18-40.
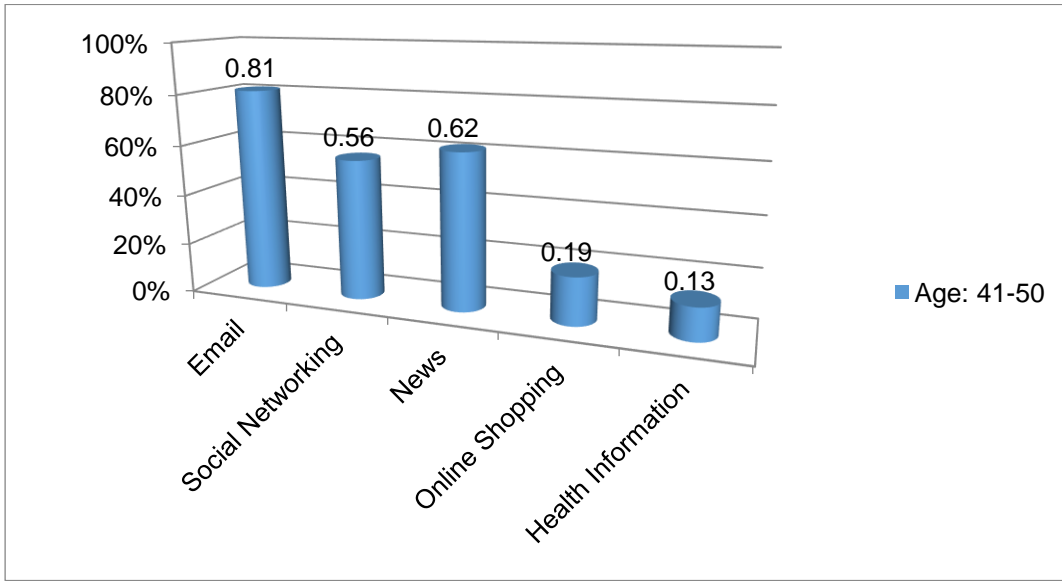
Figure 3.6 Web usage age 41-50.
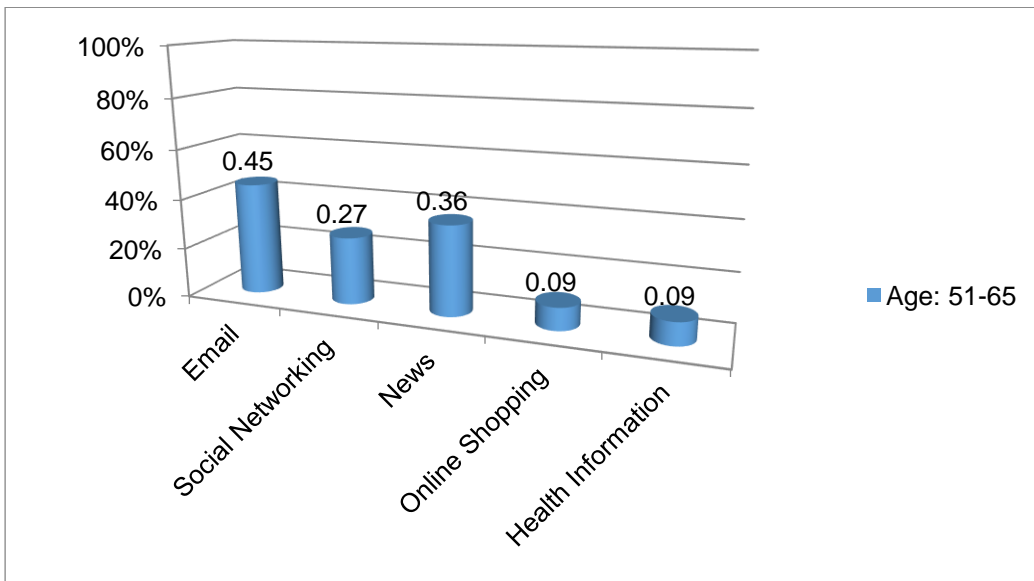
Figure 3.7 Web usage age 51-60.
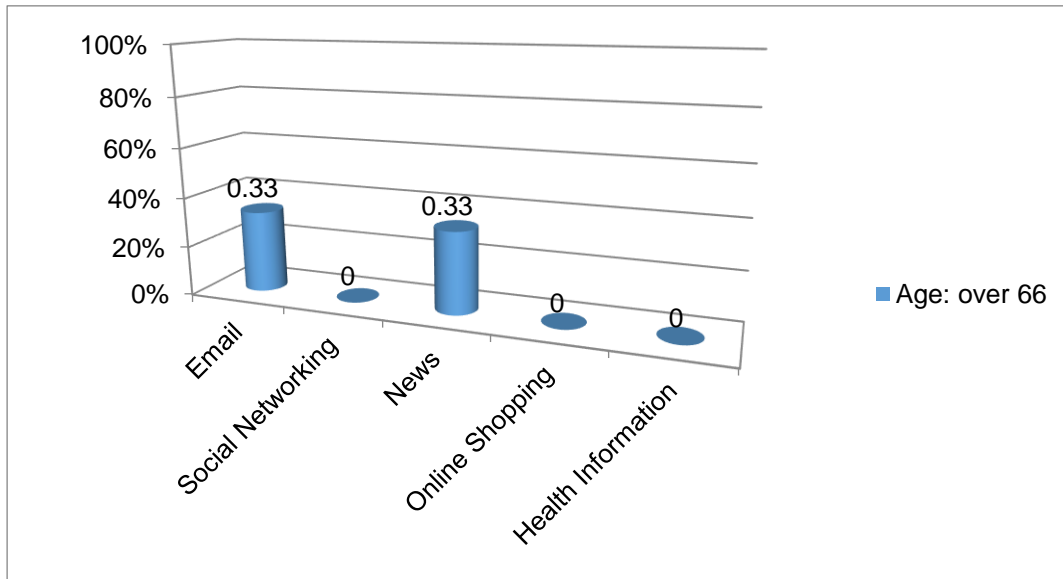
Figure 3.8 Web usage age over 66.

The results have shown a clear correction between the age and web usage, so the younger the participants the higher web usage across most activities, particularly in using emails and social network. Despite the high usage in some activities the findings show very low usage of online shopping and even lower usage of available health information. This might be explained by a lack of trust in the web for financial transactions and/or lack of online education in web usage. The low usage of health information can also be explained by lack of trust in the accuracy of available information and the availability of information in the local language, as well as possible cultural issues. In addition, while the results obtained from the over 66 year old participants are within the expected range, the sample is too small for conclusive results.

Furthermore, the following key points emerged from the analysis of the second part of survey responses (see   Figure 3. - Figure 3.):

➤ 88% (n=59) of respondents would like to have a unique web-based portal and system for managing infectious diseases.

➤ 85% (n=57) of respondents would like to receive education using a web-based system for providing help in infectious diseases management and avoidance.

➤ 88% (n=59) of respondents preferred to use social networking as an intervening module for IDM.

- 90% (n=60) of respondents would like to view the spread of infection using maps.
- 82% (n=55) of respondents would like to receive real-time feedback by e-mail or SMS.
- 100%, 100%, 90%, 67%, 98% and 99% of participants prefer particular services and features to be in the proposed system, namely: alert, trend chart, messaging, sharing video, book appointment, and immunization board respectively.
- 100%, 90%, 87%, 85% and 84% of participants showed clearly the need for privacy and security, easy to use, availability, reliability and performance in the proposed system.
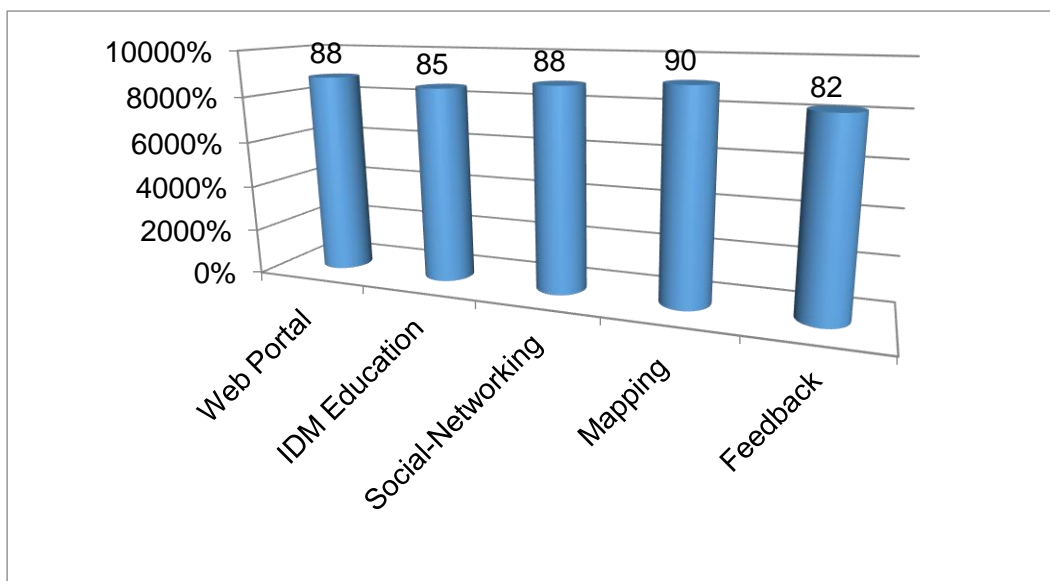
Figure 3.9 The identification of main requirements.
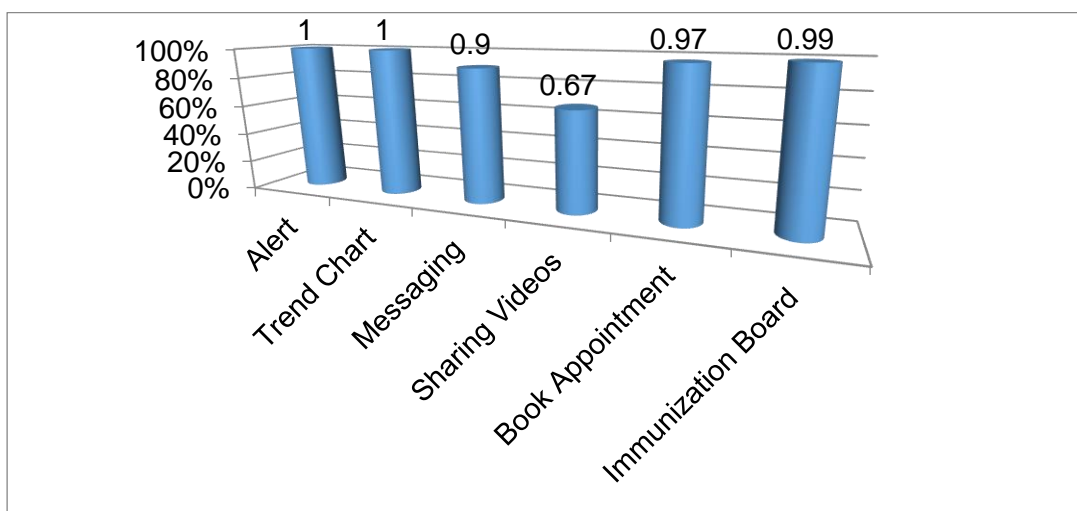
Figure 3.10 The identification and analysis of the web elements to be used in SAIF.
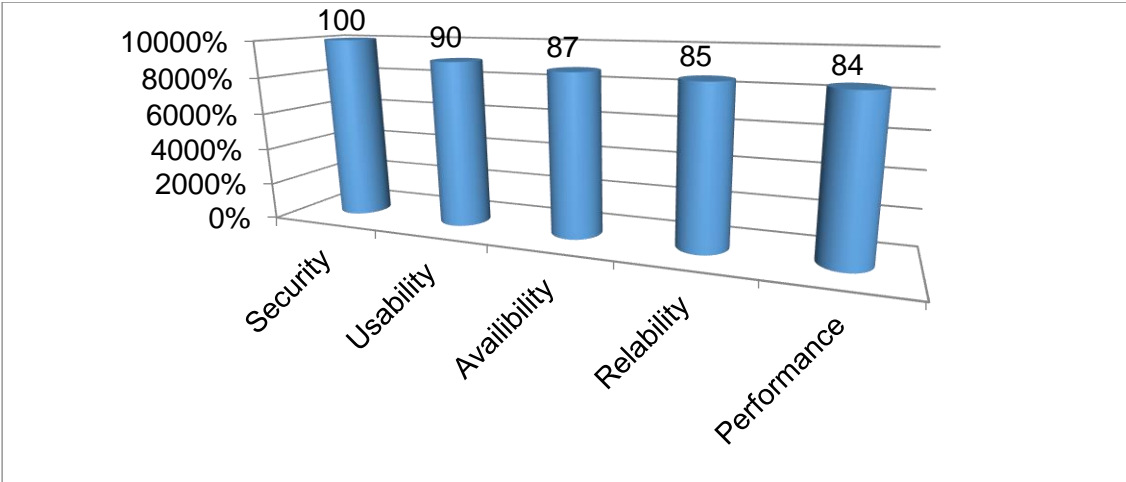
Figure 3.11 The identification and analysis of the non-functional requirements.

The analysis of the responses from participants shows clearly the main requirements for SAIF and their importance. The majority of the identified requirements have been agreed by above 80% of the participants. However, it is notable that aspects of trust such as security, and aspects of interactions such as alert and trend charts are extremely important.

3.4.1. SAIF Requirements and Their Classifications

The first (interview) and second (survey) phase preliminary studies for requirements gathering for developing SAIF System has covered wide areas of systems operations and functionality. The raw (business) requirements outlined can be observed in the previous sections. However, they need to be converted into system requirements, i.e. machine understandable requirements. This section identifies the system requirements for SAIF based on the preliminary study explained in the previous section.

As mentioned earlier the system requirements can be grouped into both functional and non-functional requirements. In addition to the functional and non-functional requirements classifications, functional requirements are grouped and categorised according to the operations (services) and entities that are used to provide a specific functionality. The process starts with infectious disease management (IDM) including description of infections, recommendations, resolutions, guide, outbreak etc. Then mapping and tracking services (MT) which include visualisation of infection spreading can assist in the identification of

trends and possible prediction. This is followed by user management services (UM) such add, delete and update users' information. Finally, the way users communicate is managed by social networking services (SN). Such a grouping will be useful when translating the requirements into design diagrams such as use case diagrams and system architecture. A summary of high level specifications for both functional and non-functional requirements is shown in   Table 3.1.

Table 3.1 SAIF Requirement Specification.

Infectious Diseases Management Framework for Saudi Arabia (SAIF)			
Requirements List			
Requirement			
No	Description	Group	Comments
1.	The system should provide infections management functions.	IDM	**Functional Requirement:** The system must allow privileged users to add, delete and update infections, their descriptions and associated guidelines.
2.	The system should be able to deal with any types of infections.	IDM	**Functional Requirement:** The system must be generic with many possible deployments such that the system can be used for different types of infections.
3.	The system will be able to accept updates and feedback for its medical information knowledge base.	IDM	**Functional Requirement:** The database must be designed in such a way to be able to deal with new data elements, i.e. it is able to expand with no changes to its core.

4.	The system should offer recommendations and guidelines which are validated by medical professionals.	IDM	**Functional Requirement:** The system must be able to assist by offering recommendations based on the stored data and knowledge.
5.	The system should provide mechanisms for tracking and mapping identified infections.	MT	**Functional Requirement:** The system must be able to assist medical professionals and policy makers to track and map infections to geo-locations.
6.	The system should provide user management functions.	UM	**Functional Requirement:** The system must allow administrators to add, edit and delete users of the system.
7.	The system should provide search function across the web portal.	UM	**Functional Requirement:** The system must provide a means to allow the users to search the database through the website portal, for relevant information such as specific queries, advice and guidelines.
8.	The system should enable the users to recover their login and password.	UM	**Functional Requirement:** The system needs to allow the users to recover their credentials if needed.

9.	The system should allow the users to submit feedback.	UM	**Functional Requirement:** The system needs to provide a mechanism to submit their feedback, comments and suggestions.
10.	The system should allow all registered users to use a messaging service that supports different forms of communications and networking.	SN	**Functional Requirement:** The system should provide a messaging service for all users to communicate with each other, and to post messages on the social networking service.
11.	This system should keep a record of all login activities.	UM	**Functional Requirement:** The system could track the number of activities including logins.
12.	The system should maintain a good level of response time, and take into the number of users.	SAIF	**Non-Functional Requirement-Performance:** The system should be operated with good performance for large number of users.
13.	The system should be able to deal with big data and be able to expand accordingly.	SAIF	**Non-Functional Requirement-Scalability:** The system should be able to scale as the volume of date increases.

14.	The system should deploy advanced security mechanism to avoid unauthorised access.	SAIF	**Non-Functional Requirement-Security:** The system should deploy the latest security and encryption techniques to protect user privacy and increase user trust in the system.
15.	The system should deploy different logging mechanisms and setting different privileges and access levels to users based on their roles.	SAIF	**Non-Functional Requirement-Security:** The system should deploy mechanism to allow the users the access to the right and relevant information.
16.	The system should be easy to understand and easy to use and interact.	SAIF	**Non-Functional Requirement - Usability:** The system's graphical user interface should be easy and clear to follow without a steep learning curve. It should be simple and should take cultural aspects into account.
17.	The system should have a complete and easy to follow manuals covering the different aspects of its operations.	SAIF	**Non-Functional Requirement – Usability and maintainability:** The system should be well documented. It should not only easy to use but also to maintain. This can reduce the efforts spent on training new administrators and the different potential users.

18.	The system should have clear help and instructions on how to use the system on the main pages.	SAIF	**Non-Functional Requirement - Usability:** all the main pages should have help links which are easily accessible thus providing guidelines and help for the different types of users.
19.	The system operation should be continuous and down time should be minimised.	SAIF	**Non-Functional Requirement - Availability:** The system should be highly available with down times, even prescheduled down times, well minimised and users should be advised with plenty of notice of any maintenance shutdown.
20.	The system should have a high response rate and low failure rate.	SAIF	**Non-Functional Requirement - Reliability:** The Probability of failure should be low, and the response time should be high.
21.	The web front end of the system should operate correctly on common browsers.	SAIF	**Non-Functional Requirement - Interoperability:** The system should support many common browsers such as IE, Chrome and Safari. It should use frameworks such as bootstrap to support all mobile phones and tablets.

3.5. SAIF Requirements Analysis- Discussion

Before proceeding to the next step, i.e., design of SAIF System, it is essential to review the major outcomes of literature review and the preliminary study conducted for collecting the requirements, so that, an effective set of requirements with up-to-date and effective technologies can be integrated into the SAIF Architecture and design. Firstly it is understood that IDM is an important and complex process and can be institution specific or community (government) specific and involves various stakeholders from common man to the high level analysts experts in health related aspects and technology [41-46]. It is also observed that there is an urgent need for developing an effective IDM System in Saudi Arabia by considering various reasons like rapid increase in the growth of infectious disease, increasing population, strong cultural and religion beliefs, high levels of international tourism (Hajj Piligrims), and most importantly lack of nation specific guidelines with poor healthcare infrastructure [47-54].

From the review of existing IDM Systems [141-147], it can be understood that an effective IDM System must focus on all health related aspects, must include users from all regions, require effective analysis tools, multi-lingual, with web-based open (free) access to expand its reach. However, the systematic review of previous studies focusing on health related technologies [56-58], and technologies including social networking and mapping [134-140] has identified various functionalities and technologies that would help in developing an effective IDM System. It is interesting to find that no existing system/ project reviewed in the literature review integrates social networking module into its system, although few systems provided mapping and tracking functionality. The review has also identified that the web-based applications can be more effective for data analysis and viewing compared to the mobile applications. It was observed that social networking can enhance the functionality of IDM System and increase its efficiency [134, 135].

Contemporary to these observations, it is observed that the number of social networking and internet users in Saudi Arabia are increasing rapidly, which makes it more feasible for the development and deployment of SAIF System in Saudi Arabia. Considering the various

points and outcomes of the studies reviewed, the following functionalities were outlined which make SAIF System novice and effective.

- Integrating Social Networking Module with IDM System for increasing its reach, and for supporting activities like education, awareness, and real-time data updates.

- Using Web-based Platform, which can be more effective for data viewing and analysis. In addition it can be even accessed on mobiles, ensuring remote connectivity and access as it is based on the internet technology.

- Ensuring the wide reach of users through social networking and involving patients and users as important stakeholders in information gathering and reporting. Unlike other projects reviewed, which mainly rely on the media and internet sources, SAIF System would directly involve the people (patients and users) for information updates, monitoring health related aspects and also in delivering healthcare services.

- SAIF System is provided with open access where users can register for free and access any health related information or view the infectious disease related information over maps and can track them using various tools. Mapping and tracking functionality is one of the unique functionalities that is being implemented in Saudi Arabia, which can assist policy makers in tracking the infectious disease outbreak and can foster them in responding to the threats early or within time.

Based on these technological outlines and the requirements gathered in the preliminary study, the SAIF System is designed and developed which has many functionalities that make it effective and novice IDM System in the region. The design process of SAIF System is explained in the next sections.

3.6. SAIF High Level Design

SAIF is a novel infectious diseases management framework with the aims of managing, identifying and tracking infectious diseases, and supporting health professionals

and patients. It is designed and developed for a particular geographical and cultural environment, namely the Kingdom of Saudi Arabia. The framework addresses the main challenges related to infectious diseases management in KSA as identified in the previous chapter including geopolitical aspects such as large mainly desert country with many sparsely populated areas and lack of government policy and guidelines. A particular challenge is the annual pilgrimage season (Haj) when millions of people from different parts of the world converge on the KSA, thus creating an environment where infectious diseases can easily spread. In addition, there are no effective systems for tracking and managing infectious diseases, which has been shown during the recent outbreak of MERS-CoV virus. Moreover, the rapid population growth combined with increasingly unhealthy diet and lifestyle, and the lack of knowledge of healthcare are leading to many diseases ranging from coronary diseases and diabetes to infectious diseases like SARS-CoV and MERS-CoV.

SAIF project aims to manage infectious diseases, make use of the social network, and provide smart maps and statistics for the policy makers associated to the spread infectious diseases and patient status in an area. Hence, in order to satisfy the project desires, several service APIs are designed to comply with the requirements of the projects. SAIF system includes several APIs such as diseases API, Appointments API, Blogging API, Policy makers API, Messages API, and etc. These API can have the following functionalities, asexamples, 1) manage infectious diseases, 2) make use of the social network, and 3) provide smart maps and statistics for the policy makers associated to the spread infectious diseases and patient status in an area. The promoted APIs interact with each other in order to build the SAIF system and make use of the proposed scenario to be implemented in Saudi Arabia.

Furthermore, there are cultural aspects such as strict religious practices, including social and cultural issues, and prejudices to infected people which are common among some of the population. High dependence on expatriates to work in the hospitals and the various healthcare models also raises cultural problems in the delivery of healthcare services. All these challenges and problems contribute to the many restrictions to an effective implementation of infectious diseases management. The proposed framework addresses many of these challenges by encompassing different components (modules) dealing with the different infectious disease management aspects and different categories of the identified

problems. For example, one module will be dealing with the geopolitical and management aspects of infections. Another module will focus on tracking and predicting the spread of infectious diseases. In addition, help and support using online guidelines and deploying learning and social interaction will be dealt with in a separate module. Another module can be dedicated for user managements. All modules are integrated to form a smart web based system which will offer accessibility to wide geographical areas and availability to not only health professionals but also to ordinary citizens.

In addition, SAIF will address many of the issues associated with previous approaches such offering specific and separate functionalities, for example some systems offer only infections description and guidelines, others offer only infection tracking and mapping with no prediction, and no integration with social networking tools. Thus, unlike other approaches SAIF will offer a unified system that integrates multiple functionalities including the storing of information about infections (cases) and patients with recommendations, together with elements of prediction, mapping and social networking.

Fundamentally, SAIF will be designed to deal with different types of infectious diseases, their symptoms, identification, recommendations, tracking, geo-mapping and predictions together with message and information exchanges and feedback to both patients and medical professionals. Thus, SAIF will need to store patients' details, history, conditions and any relevant health related issues. The health professional such as doctors, nurses, carers will also need to be considered. There are also other types of data that reflect the entities needed by the system which are discussed in design stage of SAIF. Furthermore, SAIF will have different types of users (actors), with different privileges i.e. different authorised access to different parts of the system. These include ordinary users, medical professionals, system administrator(s) and policy makers. It is important to note that the users can be both acting on the systems i.e. using it as external actors and be part of the system for example be patients.

The high level architectural view of SAIF include the client(s) supporting the frontend of the system and graphical user interface (GUI) for different types of users, the middleware component supporting the operations and the logic of SAIF, and the backend data repository where data is stored. Also shows the flow and connections between the

various components in order to meet the project requirements and the overall aims and objectives of SAIF.

The main functionalities of the different components are presented as follow:

- **Web-based user portal:** This represents the client component that supports ordinary users of SAIF such as patients. It will offer a simple and easy to use interface which can help the users' requests/operations such as communicating and querying the system for advice and guidelines.
- **Web-based administration/professional portal:** This represents the administrative component of the system that supports the management of users, infections, communication, social networking, mapping and reporting facilities.
- **Internet:** Since the system is web based, the internet supports the communication between the client components and other parts of the system. The use of internet offers wide and continuous availability.
- **SAIF Core System:** This is the core of SAIF which is made up of different modules to support users' operations such as infectious diseases and user management, mapping and social networking. It acts as a middleware between the frontend clients and the backend data storage components.
- **Data Repository:** This where SAIF data is stored.

3.7. SAIF Architecture and Design

Following a comprehensive requirement analysis, which was quantified by interviews and questionnaires, the next stage in the development of SAIF is the system design. At this stage the requirement specification and the associated operations, services, logic, and entities are translated into a graphical design solution using a variety of diagrams. This is also an important stage as it provides an overview of the services in the form of use cases and architectural design thus reflecting the way SAIF system functionalities are coded and implemented.

The graphical tool used in this work is the Unified Modeling Language (UML) which is the most widely used design tool. UML is a language for specifying, visualizing, constructing and documenting the artifacts of software systems, as well as for business modeling and other non-software systems. The UML notation is rapidly becoming the standard for drawing

design diagrams. It has grown out of the work of Rumbaugh, Booch and Jacobson who pooled their independent approaches [86] in the early 90s to create UML and is now maintained as a standard by the Object Management Group [87]. UML supports a variety of diagrams such as use case diagram, class diagram, sequence diagram, deployment diagram and component diagram.

3.7.1. Use Case Diagram

A use case diagram provides a view of a system that emphasizes the behaviour as it appears to outside users. A use case model partitions system functionality into actions ('use cases') that are meaningful to external users ('actors'). The actions represent the functional requirements of the system. An actor is someone or something that interacts with a system and it represents a role for example a person or process that can interact with and initiate actions on the system. In summary, the use cases and actors, making up a system are collected together on a use case diagram. The system is shown within a box containing use cases in ellipses and actors are shown outside the system but with lines connected to relevant use cases. Additional information about this use case is such as that, the user can search, track, post, delete, modify, send feedback and login to the system. The possible primary actors in this system could be administrator or a policy maker, and secondary actors could be medical and user. A high-level use case diagram of the SAIF system is presented in figure 3.13.

SAIF

Add user

Edit user

Administrator

Delete user

Medical

Edit infection

Professional

Add infection

Add recommendations

Delete infection

Edit recommendations

Delete recommendations

Login

Policy
Maker

View map

User

View infection

Search system

View advice/message

Track infection

Post message

Send feedback
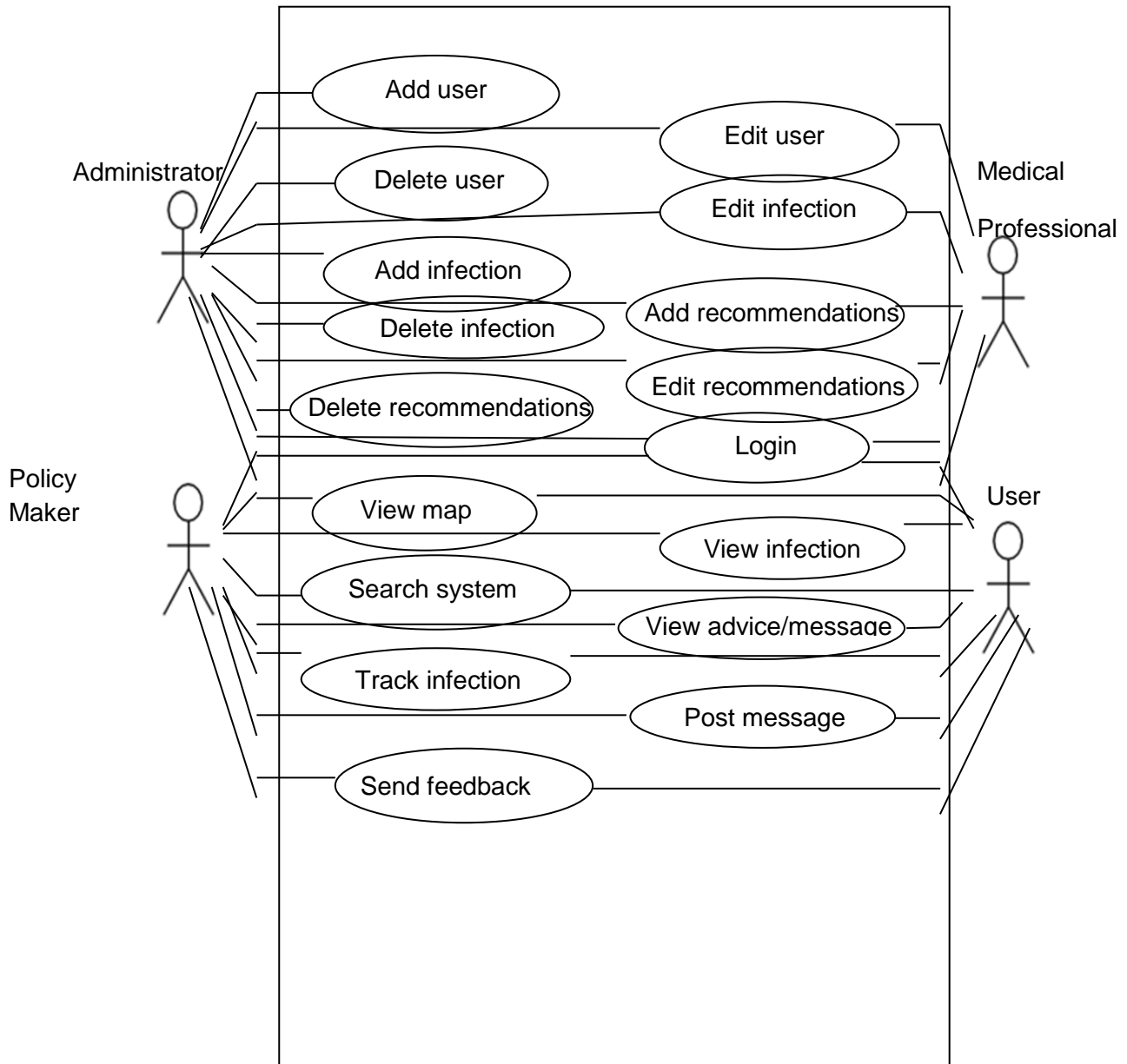
Figure 3.13 SAIF Use Case Diagram.

As mentioned above the use cases depicted in figure represent high level view of the system, but some operations in the system and their flow, how it operates as discussed in the following section.

3.7.2. SAIF Architectural Design

Having identified the functional and non-functional requirements, and having produced a view of the system using use cases and actors (services and users), there is a clear need to identify SAIF main entities as part of the architectural and implementation consideration.

3.7.3. SAIF Main Entities and Attributes

SAIF will be designed to deal with different types of entities. Although infections and users are the main entities of the system, meeting the project requirements needs others such as outbreak, recommendations etc. which are listed below:

Infections: These are generally used to represent infectious diseases (problems) and all their associated information that will be stored in the system. These include:

- The name(s) of the infection both the scientific and no-scientific names as known by the professional and ordinary users.
- A detailed description of the infection.
- Steps for dealing with infections and treatment.
- Guidelines for prevention the infections and help for ordinary users.
- The identification and symptom(s) that indicates the possibility of the infection's presence.

This is the sort of detailed data that is very important in assisting the professionals in their diagnosis and providing some advice to ordinary citizens. The infections description needs to be supplied by medical professional.

Patients: These are used to represent the host(s) of an infection, and all the patients' information that will be stored in the system. These include:

- Personal details such name, date of birth, address etc.
- Family details.
- Medical history.

- The identification and symptom(s) that indicates the possibility of the infection's presence.
- A detailed description of the infection with date.
- List of contacts with their geographical locations for tracking.
- Places visited and transport with dates.

Identifications: These are used for linking a described medical condition or an emerging situation leading to infections. The identification links refer to expressions or conditions that point to the existence of an infection or an emergency situation. This may be symptoms of an infection, and the way the body react to it, which call the attention of the medical staff. The links are stored independently in SAIF but they are associated with the infections that they identify. This is because it is possible more than one infection can be identified with the same symptoms and conditions. The identification entity also links the patient and the infection to a set of recommendation and resolution steps, for example tests, possible isolation etc. that will be required for the treatment of the patient. In addition, the entity provides link to any potential outbreaks.

Outbreak: The outbreak entity deals with a sudden and rapid increase in the number infections in a geographic area. Depending on the size of area this can also represent an epidemic within a population. Thus, this entity includes the number of cases, speed of the spreading of infection, link to mapping the spread of the outbreak. It also recommends guidelines and implement control measures to contain transmission such as quarantine and isolation of cases, vaccination those unaffected etc.

Recommendations: Recommendations represent the suggestion(s) that the system provides in response to a case involving infection that has been identified, including the potential for outbreaks. Recommendations represent a specific description/guide showing a step by step procedure as to how to deal with the identified infection. Since many infections may have similar symptoms, for example high temperature, it is important to note that some steps, particularly the early ones, in the recommendations process might be associated with more than one infection. But as more details about the infection are entered the recommendations become more specific, and the final steps in the procedure should be defining a particular path or course of actions.

Resolutions: This entity refers to medical problems that have been resolved and validated by the medical professionals. Using resolutions the system will be able to help in making future recommendations. The entity includes the description of the infections, the recommendations and the validations using medical professional feedback.

Feedbacks: This is any new information, update or amendments that the privileged users such as medical professional believe necessary to improve the system particularly case description, recommendation and resolutions.

Messages: Messages represent any communications between the users of the system through the social networking part of the system. These can be private for example from patient to medical professional or feedback to system administrator, and they can be public for example asking or providing any advice or past experience etc. This entity contains the details of the sender and the date/time the message was sent. Message exchanging in SAIF also allows sharing among multiple recipients who have to be registered users.

3.8. SAIF General Architecture

Considering the key outcomes of the requirements gathering, use cases and entities identification, it is necessary to develop modules that group the associated requirements, functionalities and entities. This starts with an infectious disease management module grouping all aspects of infections, a mapping and tracking module to help in tracking, prediction and visualisation of infection spreading, a user management module and a social networking module in order to develop the full system as shown in the general architecture of SIAF and its modules, communication and client components (see figure 3.14).
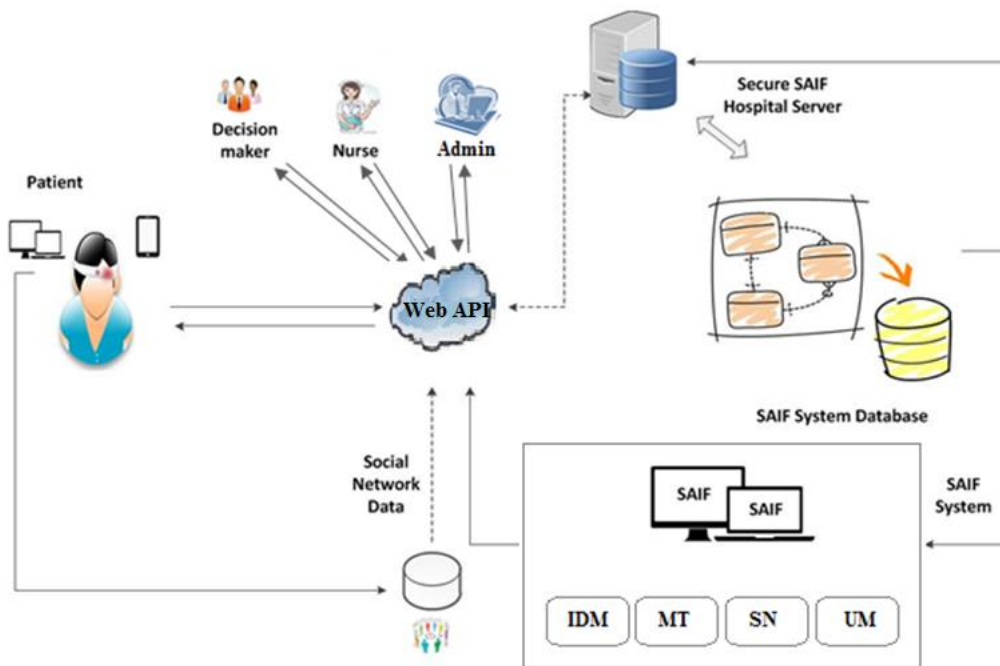
Figure 3.14 The general architecture and the SAIF modules.

SAIF is divided into four main modules: infectious disease management module (IDM), social networking module (SN), mapping and tracking module (MT) and user management module (UM) which can be accessed using a web portal, hosted by a health service provider, for example a hospital specialised in infectious diseases. These modules are discussed in the following sections.

<u>SAIF Infectious Disease Management (IDM)</u>

This is the most important module of the architecture as it is the core behind which all the other modules operations. The IDM module is designed to support a number of main SAIF functionalities and is associated with many of the entities identified. The module is responsible for managing infectious diseases, which includes setting and adding diseases with their high level description, symptoms, stages, methods of treatment including procedures such as isolations etc. Moreover, IDM helps in the identifications of diseases based on the stored medical knowledge, the patients' conditions input into the system, taking into account patients' history if available. It also suggests recommendations based on the

77

stored and validated by health professional knowledge about the diseases and previous resolved cases. In addition, it accepts updates and feedback and it provides guidelines not only for medical professionals but also to patients, particularly for the prevention the infections and help for ordinary users.

As mentioned earlier the recommendations represent the treatments suggestions and the step by step procedures as to how to deal with the identified infection. Using recommendations and resolutions the system will be able to help in making future recommendations advice, and links to social networking module. Moreover, it provides links to patients and user management module, and to any potential outbreaks and reporting facilities through the mapping and tracking module.

In addition to using the data such as patients and infections details that are entered into its data repository, the system stores the details of the resolved cases which can be used in future decisions of the system. This is the sort of detailed data that is very important in assisting the professionals in their diagnosis and providing some advice tailored according to the needs of the patients in the KSA.

SAIF Social Networking (SN)

Social networking allows users to communicate more effectively through active participation, information sharing, and giving emotional support. Every user has a unique profile, which can be created and modified only by the respective user, through which the users can participate in social networking. The social Networking (SN) module aims to provide an online environment for infectious diseases information seeking. This will allow health professionals to make recommendations based on their experiences, SAIF system resolutions and patients needs, and to provide support and counselling to patients. It will also allow both patients and health professionals to share and to search for medical information, guidelines, health tips etc. This will normalise the patients' help seeking behaviour which very important for Saudi citizens and will inspire lifestyles changes. Some of the social networking elements, included in the SAIF architecture, are:

1. *Messaging:* This feature allows the users of the system (patients and health professionals) to send private messages.

2. *Updating the status:* The users of the system can update their status which reflects their current mood or activity.

3. *Ask the doctors:* The users of the system can register any queries which will be forwarded to the respective doctors. This helps the patients to have direct interaction with doctors.

4. *Video Sharing:* Video sharing improves the information sharing features on the web portal, and helps to improve the knowledge of patients. This can help the patients to adopt personal management as an option in the IDM.

SAIF Mapping and Tracking (MT)

The mapping and tracking model is designed to view the infectious disease related data through a graphical user interface including maps. The data can be summarised or viewed on the maps, which can be then filtered or sorted by disease-related data: type of infectious disease; patient-related data (number of patients, age, gender etc.), and specific regions in the KSA. This would help the government healthcare decision makers to quickly collect and view the information, and can help them in taking decisions before the disease spreads further. It also helps in designing healthcare policies, disease preventing strategies, and disease monitoring and control plans.

Disease tracking functionalities like getting reminders, tracking the infection, tracking the infection vaccines, and viewing health data through charts by the patients, are also included in this module. The module support reporting facilities and mapping of statistical information, based on which events such an outbreak or epidemic can be declared. These include the type and speed of infections, the number of infections in a geographic area. In addition, depending on the size of area this can also represent an epidemic within a population. Depending on the outbreak, there are different types of control measures to contain transmission which might be taken such quarantine and isolation of cases, vaccination of those unaffected and hygiene and sanitation measures.

SAIF User Management (UM)

It has already been explained that the proposed system would be a web-based social networking portal integrated with the infectious diseases management and mapping modules, and the user management module, tailored to the needs of KSA patients, suffering from infectious diseases, medical professionals and policy makers. Therefore, the users of

the system include system administrators, medical professional such as doctors and nurses, users such as patients, and policy makers. Each and every type of users would have specific tasks and responsibilities which are visible throughout the system as listed below:

1. **Administrators:** The administrators are the users with the highest privileges and security access in the system. They are able to add, edit and delete users, any messages, infection descriptions, identifications, recommendations, resolutions etc. They can also manage security access and users' privileges including adding and revoking these privileges. Administrators do not need to have any medical knowledge but they need system administration knowledge and technical/computing skills in order to perform tasks like system updating, maintenance, data backup, user/system management etc. The administrator should be able to handle all the technical (software and hardware) aspects and issues of the system throughout its usage.

2. **Users:** some SAIF modules such as the social networking module are targeted at aiding non-professionals therefore its corresponding users are explicitly considered to be novices in the medical field particularly in infectious diseases for which SAIF is developed and deployed. They can communicate, get help, guidelines etc. through social networking. Users include patients who can access the SAIF system through a web-based portal, which can be available from a personal computer, laptop, mobile device or tablet. They can use the entire web features of the SAIF System including education, social networking, which allows them to perform different tasks like posting information, viewing their health profile, uploading their health-related information etc.

3. **Medical Professionals:** the involvement of professionals will be not only for medical knowledge acquirement but also for patient care and infectious disease management. They also have access to an administration part of the system, so they can edit information such as patient's details, infection case description, guidelines, recommendations regarding infection identification and any resolution. They also can communicate with other users. The medical staff can access the SAIF system through a web-based portal, in the same ways as patients. They can use all the web features designed for them like monitoring the information sharing, sending feedback, deleting any irrelevant information, and updating their profile etc.

4. **Policy Makers:** While not directly involved in medical decision making they need to be able to track infection outbreaks particularly through mapping in order to provide guidelines and allocate resources etc. The policy makers can also access the SAIF system through a web-based portal, in the same ways as medical professional. They can use all the web features designed for them like monitoring the infections maps, including dates, times, locations, number of infections and other statistical information that helps in their decision making processes.

3.9. SAIF Relationship Management

As mentioned earlier the frontend of the system is built using a number of client components that offer graphical user interface designed and adapted to the different types of users. In addition the backend server with the Date Repository store all of SAIF entities and their attributes, for example the entity Patients, described above, will have attributes such Patients_ID, Patients_Name, Patients_Address etc. while entity Infections will have attributes such as Infections_ID, Infections_Name, Infections_Description, Infections_Stages, Infections_ActionPlan etc. In addition, modules and entities are linked for example there is a clear relationship between Patients (Patients_ID) and Infections (Infection_ID).

As explained in the previous section, the proposed system includes four functional modules integrated to form the SAIF System. The relationship control of SAIF is represented in Figure 3.15.
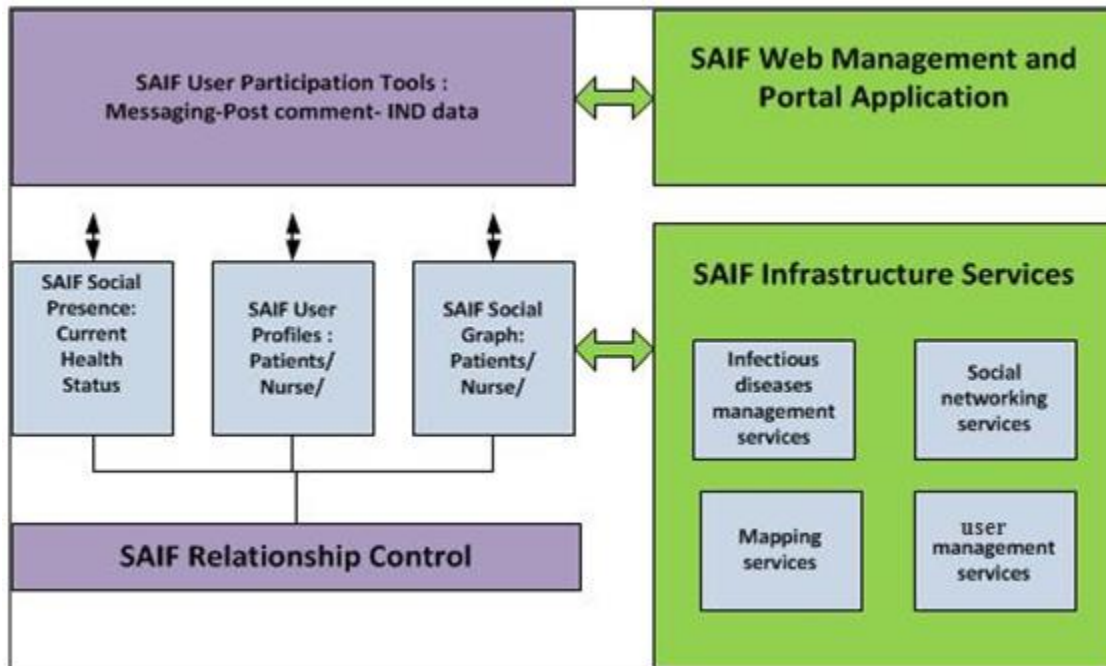
Figure 3.15 SAIF Relationship Control.

As can be observed from figure 3.15,

- The relationship between the Infectious Disease (ID) Patients and ID nurses (medical professional) in SAIF is a friendship controlled relationship.

- The social graph in SAIF architecture is represented by the inter-connectional friendship relations between ID Patients and ID Patients; and ID Patients and ID nurses.

- The actor profile of the SAIF architecture includes ID Patients, ID Nurses, and System Monitor.

- The actors/users participation tools in the SAIF system include messaging between the system's users, the ability to post information and commenting on the posts, using a blog to write articles, and the ability of ID patients to insert their health information.

- SAIF Infrastructure Services: The content and services of SAIF system are included as follows: i) infectious disease management services, ii) social networking services, iii) mapping services and iv) user management services.

3.10. Interaction and Functionalities

Interactions and functionalities of a system can be best described using use case diagrams, which present the interactions between the users of the system, usually includes set of actions and reflects the behaviour of the system. The three major components of the SAIF System including IDM, Social Networking, and Mapping and Tracking functionalities are presented using the use case diagrams in the figures 3.16, 3.17, and 3.18. User management functionality can be seen among all the three components as shown in the figures3.16.
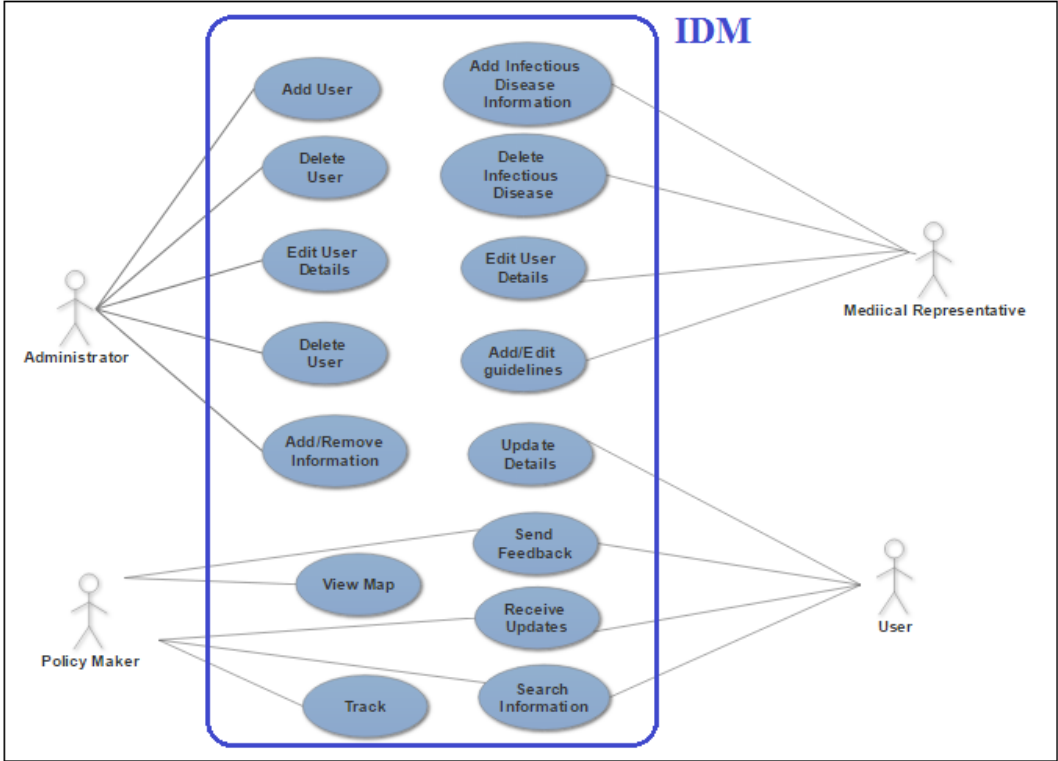
Figure 3.16. Use case Diagram for IDM component
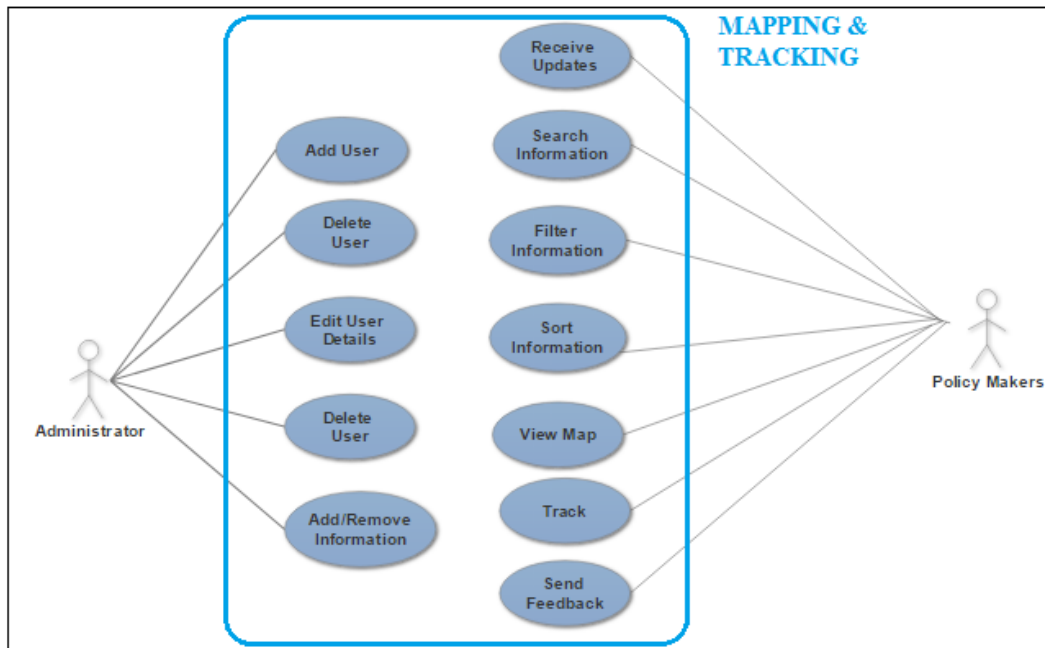
Figure 3.17. Use case Diagram for Mapping & Tracking component
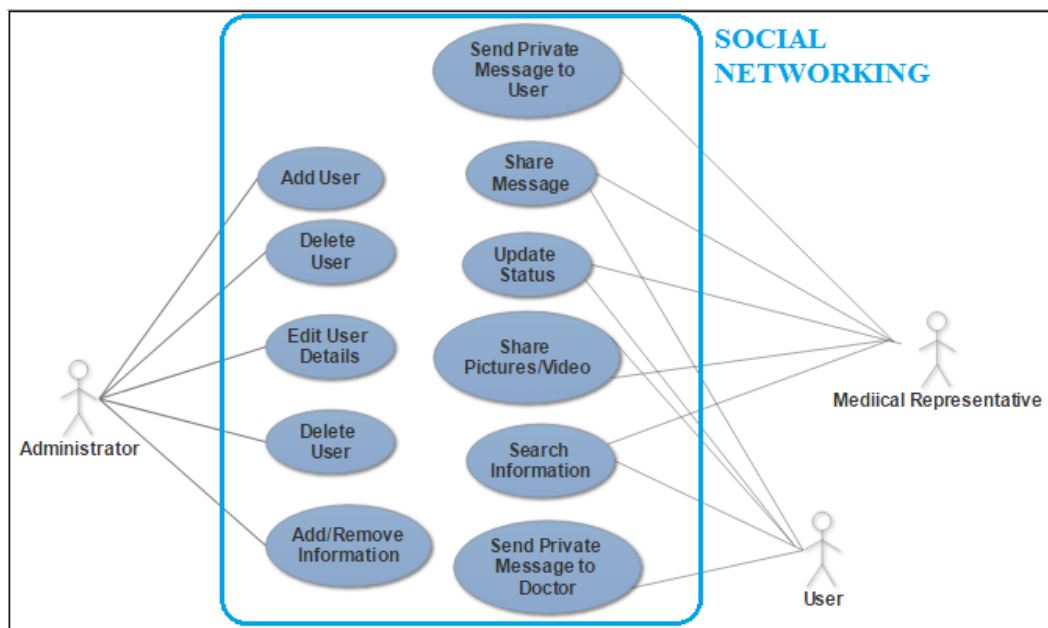
Figure 3.18. Use case Diagram for Social Networking component

Use case Diagrams can be a high level representation of the actions between the users of the system, and may not represent minute details of interactions. For this purpose, interaction

and sequence diagrams can be used. Interaction and the flow of functionality control between the different parts of a system are modelled in UML using sequence diagrams. These parts can be actors, instances of classes or components (modules) that interact using a sequence of messages. It is common to use sequence diagrams to visualise sets of events and actions that an actor can take in an ordered series to describe use case scenarios. They show the engagement of the actor with modules or objects of the system and the way the system react to each action. Since there may be different outcomes for the completion of a use case, UML sequence diagrams can be used to represent the different scenarios.

This section considers two sequence diagrams from SAIF's use cases by expanding on the two use cases illustrated earlier, starting with the "Search" use case sequence diagram (see Figure 3.19) which follow the steps:

- A user, such as a patient or a nurse, enters the search term for an item, for example an infection, on the web client and clicks next.
- The web client checks the entered data making sure it is not empty. If empty, an error message is returned to the user, if not the search item is passed on to the IMD module.
- The IMD module is activated and it carries out a search operation on the data repository using the entered search item.
- The matched results are returned to the user on the web client as a list.
- The user selects the most relevant result.
- The selection of the result triggers a request for full information, which is then returned to the user on the web client.
- The web client displays the requested information to the user.
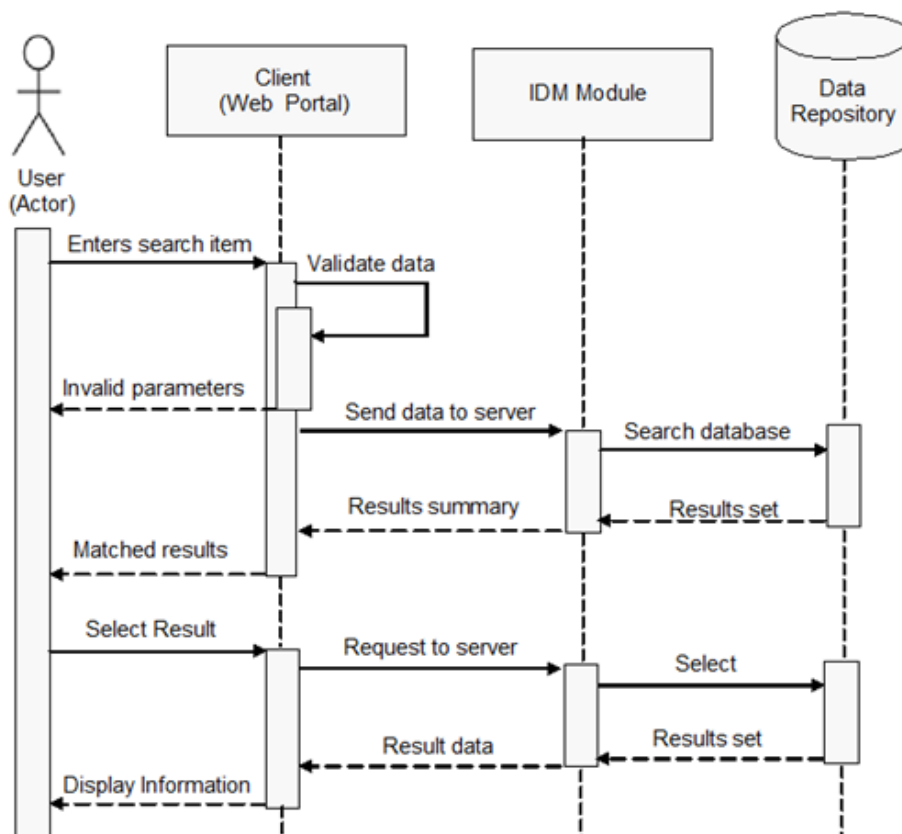
Figure 3.19 Searching the Data Repository.

Another sequence diagram example is given below (see Figure 3.20) for creating a new user:

- A new user registers on the web client and is prompted to enter a username.
- The web client checks the entered data making sure it is not empty. If empty, an error message is returned to the user, if not the user name is passed on to the UM module.
- The UM module is activated and it carries out a search operation on the registered user names on the data repository. If a name is found the user is prompted to choose another name otherwise it is added to the system
- On the web client and is prompted to enter a password. If the chosen password is weak, the user is prompted to enter another one. If approved the user is prompted to retype the password.
- The approval triggers a login request and the authorised information is then displayed to the user on the web client.
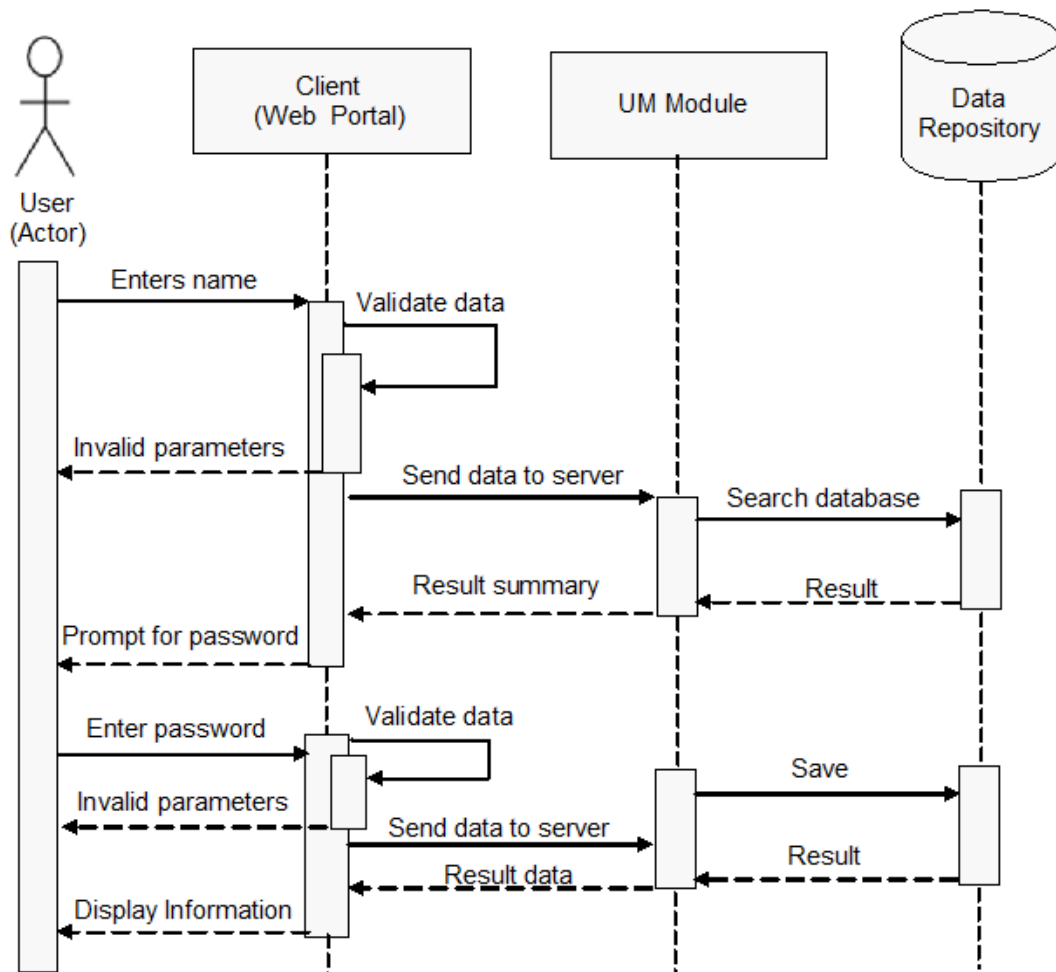
Figure 3.20 Adding a new user

3.11. Deployment Diagram

The system architecture at run-time is illustrated using UML deployment diagram which includes information about the hardware and software environment where the system modules are deployed and the way the components within the environment can communicate. For SAIF the hardware components include the physical servers and clients while the software components include web portal application, database etc. A deployment diagram for the run-time architecture of SAIF is presented in Figure 3.21.
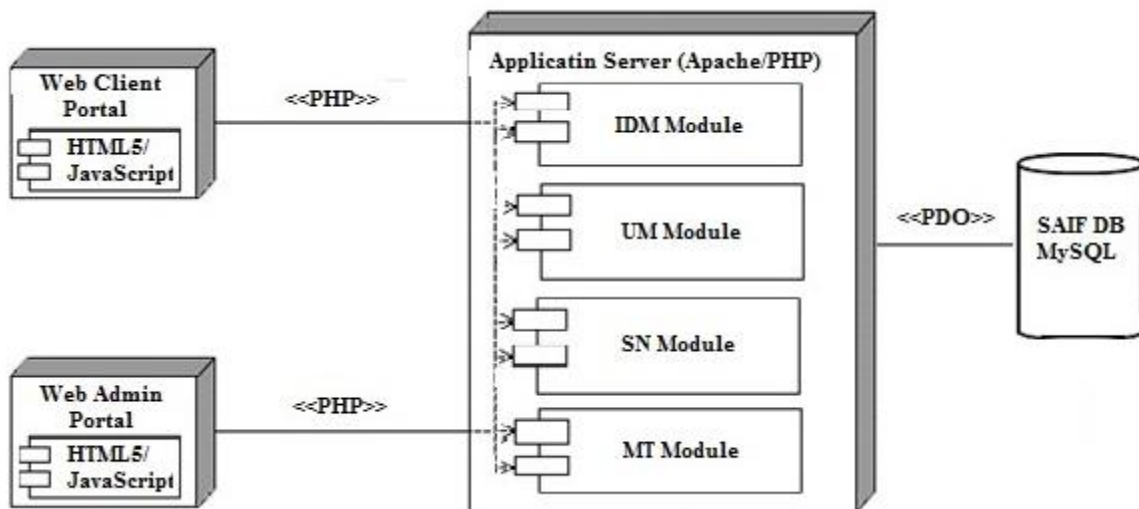
Figure 3.21 SAIF Deployment Diagram

For the implementation stage a number of technologies will be deployed to ensure maximum usability and cross-platform availability. These include HTML5, scripting languages such as JavaScript for the front end, PHP and MySQL based server for the back engine.

3.12. Conclusion

This chapter began with the definition and high level description of infectious diseases management framework for Saudi Arabia (SAIF) linking the new proposed system with the main challenges identified in the literature review chapters, both in generic terms as well as specific ones oriented towards the citizens of KSA. The methodology for the development of SAIF that combined the waterfall method with aspects of modularisation was then discussed and justified. This was followed by comprehensive user requirements analysis. The preliminary study included a survey and interviews, conducted in the KSA, of the main stakeholders i.e. patients, medical staff, policy makers etc. which identified the requirements of infectious diseases management in the KSA and demonstrated the needs as well the necessary elements of the proposed system.

Following the requirement specification, the architectural design of SAIF was proposed embedding infections disease management, user management, mapping and tracking infections and social networking modules which were tailored for Saudi users. The modules,

their functionality, entities etc. were discussed in many details and illustrated using a number of UML diagrams ranging from use case diagrams to sequence and deployment diagrams. At this point it is important to note that the suggested solution was based on both user requirements as well the state of the art review aiming to address the main challenges of infectious diseases management.

In the next chapters SAIF will be evaluated both in terms of its usability and its benefits in managing infectious diseases with a focus on patients and medical professionals as well as fighting the spread of infections among ordinary citizens.

Chapter 4: Implementation and Testing (SAIF)

The implementation and testing chapter provides an overview over the implementation of the current prototype version of the SAIF platform, including its services required for data collection, technical deployment of the platform, and a short guidance about the platform usage that navigates through some components. To this end, the chapter provides a brief overview over the various services and how they are implemented on the SAIF platform. The chapter describes the implementation in terms of the four subsystems of the SAIF project: Admin, Doctor, Patient, and Policymaker. Illustrations of the implementation for each of the subsystems are provided in the chapter.

4.1. Technologies for SAIF Implementation

4.1.1. System Wireframe and Prototyping

System wireframe:

The system wireframe, also referred to as a page schematic or screen blueprint, is defined as a non-graphical layout and a visual guide which shows the framework of a system or a website. Wireframes are designed for the purpose of arranging components. Such purposes are usually being learned by a business objective and innovative notion. The wireframe usually represents the layout or arrangements of a page used to construct the website content. This includes interface elements, browsing systems, and how they interact together. Typographic style, colour, or graphics are not provided in the wireframe, as the major focus relies on functionality, behaviour and priority of content. In other words, the wireframe focus depends on what a screen does and not on what it looks like [88, 89]. Brown and Garrett represent the database schema of the SAIF project.

Figure 4.1 Database schema
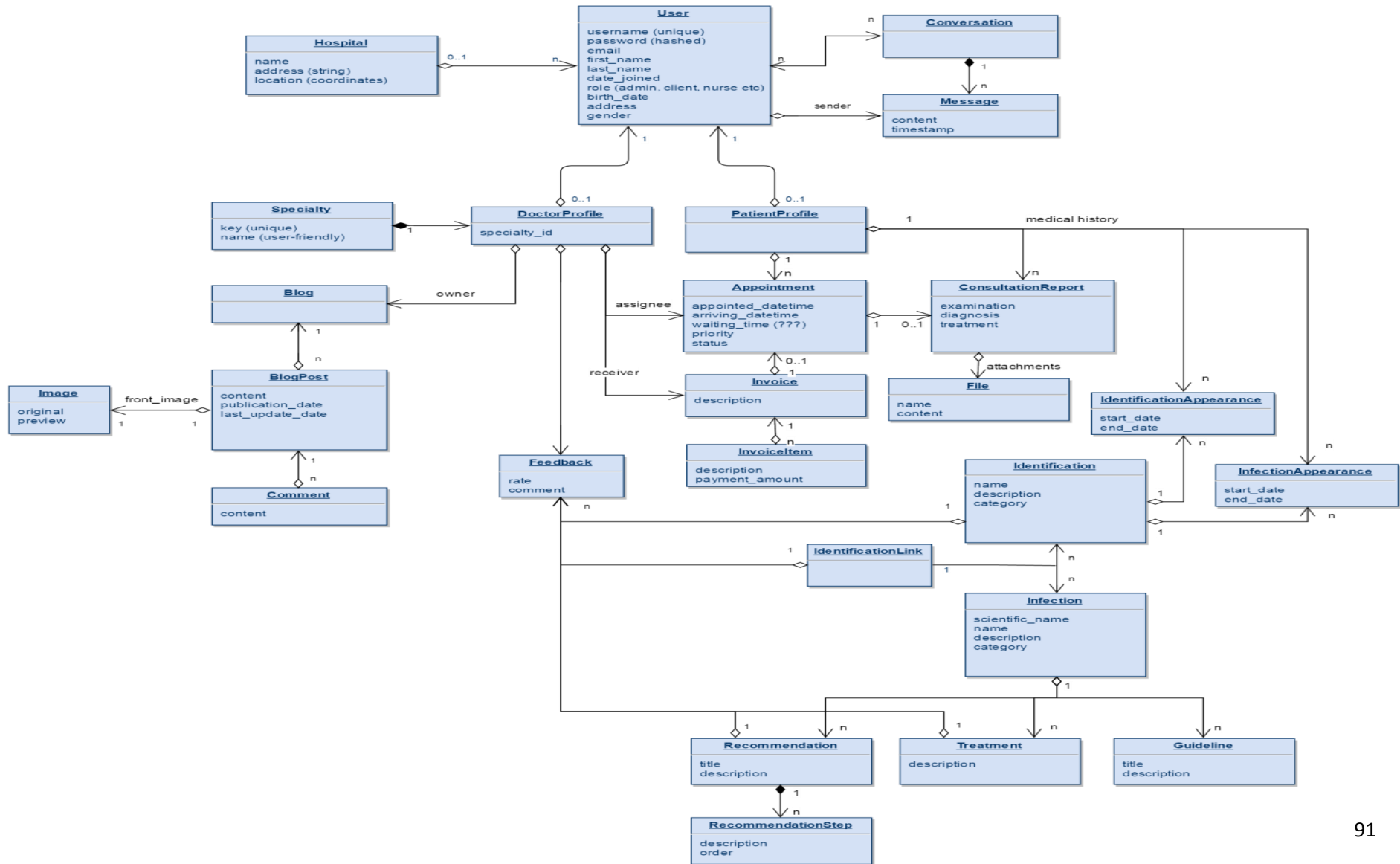
System prototyping

System or software prototyping is defined to create software applications' prototypes. In other words, it creates unstable versions of a software programme which is being developed. Prototyping is the stage when a product is being tested or simulated to examine a few aspects of the product, which could be a completely different version from the final product. This means that the prototyping of a product may have several versions until the final product is approved [90]. Figure 4.2 shows one example from our system which illustrates the prototype interface of the Appointment List API.

Figure 4.2 Appointment list interface prototype.

4.1.2. Single Page Application Technology

This section includes an overview about single page application technology.

A single page application is defined as a web application or a single page website functioning as a desktop application. The goal of single page application is to provide a flexible user experience by accessing one webpage instead of several webpages (similar to the current ordinary webpages). In a single page application, programming codes (such as HTML, JavaScript, and CSS) are invoked in response to user actions. Since single page application is represented by web applications, it is important to introduce shortly a web application

concept. The web page application is defined as a client-server software application. Further, the client or user interface of the web application runs in a web browser. Examples on web applications are such as webmail, online auctions, and instant messaging services. In short, web applications are similar in terms of functionalities to mobile applications and desktop software applications [91, 92].

Web services and API technology

This section includes an overview about web services, web API and representational state transfer. Web services and API technology are important in our study because integration of a system with other subsystems is needed. Also, web services and API technology provides high security, reliable and fast connection, and flexible availability over time. Hence, Hospitals and governments in Saudi Arabia will need such technologies and features (i.e., they should be web service and API –aware) in order to provide high-level quality assurance.

Web Services

A web service is defined as a service that offers a communication between an electronic device to another electronic device through the World Wide Web (WWW). For instance, a web service such as HTTP is used to provide a machine to machine communication such as transferring machine readable files like XML and JSON from one device to another over HTTP [93].

Web API

A web API stands for application programming interface for a web browser or a web server. The concept of web API is referred to as a web development which is constrained only to a client's side web application. Additionally, this type of web development does not contain browser implementation or web server details such as SAPIs or web browser engine APIs [94].

Representational State Transfer

Representational state transfer is abbreviated as REST. It is defined as an architectural style of the WWW, containing organised and directed set of components, connectors, and data

elements inside a distributed media system. With REST, the focus mainly is on component roles and certain interactions among data elements instead of considering implementation details. The purpose of REST is to influence scalability, visibility, performance, portability and reliability [95].

Front End Development

This section introduces briefly the essential programming languages such as HTML, CSS3, JavaScript, Bootstrap, AngularJS, and JSON that were an integral part of the development of SAIF system.

HTML

HTML stands for HyperText Markup Language. HTML is a commonly used standard to create web pages. HTML is usually used along with CSS and JavaScript to create, in addition to web pages, user interfaces for web and mobile applications [96].

CSS3

CSS is defined as a style sheet language which also stands for Cascading Style Sheet. CSS is normally used to design, describe, and style the presentation of a written document in HTML (i.e., a markup language). The primary goal of CSS is to allow separation of the contents in a document from its representation such as colours, fonts and layout [97].

JavaScript

JavaScript is a high level programming language which was standardised in the ECMAScript language specification. JavaScript works alongside HTML and CSS, and it is considered as one of the major technologies of WWW content generation. JavaScript is mostly supported by all web browsers without plugins [98].

Bootstrap

Bootstrap is an open source front end framework used to design websites and web applications. This framework consists of designed templates based on HTML and CSS such as buttons, forms, navigation, and interface components [99].

JSON

JSON is an open standard which uses human-friendly text to transfer data objects containing pair of attribute values. It is the most commonly data format used for asynchronous communication between a browser and a server (so called AJAJ). In other words, JSON is taking XML place which is used by AJAX [100].

AngularJS

AngularJS is a complete client and server side open source web application framework based on JavaScript. This framework is maintained by Google and professional firms and individuals, in order to fix and address the issues and challenges obtained while developing single page application. The aim of Angular JS is to simplify the testing and development of web applications. This is achieved by a framework for client called model view controller (MVC) and model view view model (MVVM) architectures [101].

The AngularJS operates firstly by reading the HTML page which has customised tag features. The framework translates these features into directives to fasten the input or output of the page to a model. This model is represented by standardised JavaScript variables. These JavaScript variables can be manually set with values inside the code or invoked from dynamic or static JSON resources [102].

Back-end

This section introduces an introduction about python programming language and Django web framework.

Python programming language

Python is a high level and dynamic programming language. The feature of python is its simplicity in writing programs to express its concepts in fewer lines of codes compared to other programming languages such as C++ or Java [103].

Django

Django is an open source framework written in Python. This framework follows the MVC architecture and it is maintained by Django Software Foundation (DSF). Django aims to facilitate the production of complex and databased oriented websites. Reusability of components and fast development are featured in Django. Another feature of Django is providing an optional administrative read, create, delete, update interface that is created dynamically via introspection and configured through administrative models. Examples of some websites that use Django are Instagram, Mozilla, and Nextdoor [104].

4.2. SAIF Platform Implementation

The implementation of the SAIF project aims to manage infectious diseases, make use of the social network, and provide smart maps and statistics for the policy makers associated to the spread infectious diseases and patient status in an area. The implementation is described in terms of four actors (administrator, user, medical staff, and policy maker) that were presented in the use case diagram of Figure 3.13.

Administrator Case

The administrator of SAIF is responsible for management and maintenance of the system. They are provided with various tools and interfaces that enable them to perform their tasks. The implementations of various API to administrators are described below.

A. General API Format

The General API allows the administrator to conduct daily maintenance tasks related to the SAIF portal. The project objects can be classified into two formats: single object or list of objects. The single object format contains the object itself which is located at top level of returned JSON data. However, the lists of objects are more complicated and they are listed as follows:

- Pagination is developed using a "limit-offset" concept (i.e., a page size is specified by a parameter called "limit", a page number is specified by a parameter called "offset" which also specifies the number of skipped instances from the beginning of the entire list;

- Pagination parameters should be given as GET, and the parameters are named as "limit" and "offset";

- The default page size (limit) is 10 instances;

- They are always paginated;

- The default offset parameter is 0.

The list of objects which are involved in the next data structure are the following:

```
{
    // total number of objects (regardless of pagination)
    "count": 13,
    // URLs to retrieve next and previous page of the list
    // In fact, it is same URL, as requested, but with *offset* increased or decreased by
*limit*
    // If there are no next or previous page, corresponding field will be `null`.
    "previous": null,
    "next": "/same/url/as/requested?with=same&params=saved&offset=10",
    // Returned instances list itself. Number of instances is less or equal to "limit" value
    "result": [... instances ...]
}
```

B. "Brief" and "Detailed" representations

Typically, representation of an object in a single-formatted output is equal to representation of objects in a list-formatted output except for the next caveat. Some representations may have fields with large amount of data. In this case, the list-format output representations omit these fields and they should be perceived as brief representations instead, whereas single-format representations should be perceived as detailed representations.

Of course (typically but not always), APIs can also provide a way to receive "detailed" fields in lists. For this purpose, APIs provide the query parameter named "select". It accepts comma-separated list of fields which should be added to representation.

Each API can include "brief" representations in lists, omitted fields of a document in other lists, and either of these lists can be selected. If an API documentation does not mention anything about the above details, then the list-format representation is equal to the single-format representation. Hence, there would be no "brief" variant of representation, no omitted fields, and no "selectable" fields provided.

C. Standard errors

There are three types of common errors: 1) user is not authenticated, 2) validation fail and 3) user is not permitted. The appropriate errors are provided for these standard errors and will be displayed to the user and the log of the errors will be available to the administrator. The errors displayed are provided in Appendix C.

User`s Manager API

The User manager provides an API to the administrator to create, list, update, and delete prosperity metrics. This API includes two parts: basic information and profile. The Basic information contains data that is generic to all users regardless of their roles. However, it is not possible for all users to have profiles. The profile, instead, contains data that depends on a user`s role. Currently, Doctors and Patients are the only users who have profiles.

A. User information representation

The following structure represents the user information example, where the following points should be noted:

- The *username*, *date_joined*, *role*, and *gender* fields should be **always filled.**

- The mail, first_name, last_name, birth_date, address, phone, mob_phone, and bio fields can be empty, but there presence is essential.

- The *profile* field maybe null sometimes. This happens when a user doesn't have a profile because this is based on the user`s role.

- The email, first_name, last_name, birth_date, gender, profile, address, phone, mob_phone, bio fields are writable within this API.

- All other fields are set to read-only.

B. Doctor profile representation

This profile is represented in the following structure. Some features should be noted under this profile: is_supervisor field is read-only, and a list of possible choices for **specialty** can be loaded using Specialties listing.

```
{
    // key word that specifies the doctor's specialty
    "specialty": "therapist",
    "linkedin_url": "any possible URL",
    "is_supervisor": bool
}
```

C. Patient profile

This profile is represented in the following structure. All fields are readable, and most fields are writable except for the duplicated ones.

```
{
    "emergency_first_name": "arbitrary string",
    "emergency_last_name": "arbitrary string",
    "emergency_email": "arbitrary@mail.com",
    "emergency_address": "arbitrary string",
```

```
    "emergency_phone": "+380951122333",

    "emergency_mob_phone": "+380951122333",


    // these fields are read-only and duplicates fields in user representation
for backward compatibility

    "phone": "+380951122333",

    "mob_phone": "+380951122333",

    "bio": "arbitrary long text",

}
```

D. Authentication API

Since we are implementing monolithic architecture, authentication can rely on cookies mechanism. These cookies are handled automatically by all browsers and Django framework. We don't need any tokens or CORS headers, so authentication is completely transparent for client-side. The request structure, success response, and fail response of the authentication API is provided in Appendix C.

E. Retrieve current user (Who am I)

In order to retrieve a current user, we need to go through the following steps:

      i. Request structure

Under the request structure, we write the following (URL: GET /api/myself/). And it should be noted that there is no request body, nor query parameters.

      ii. Success response:

The HTTP code related to success response is 200, and the response body consists of authenticated user's representation, which was described above.

      iii. Fail response (user is not authenticated):

The error response here will be a standard "not authenticated" response.

F. Changing personal data

The email, first_name, last_name, birth_date, gender, address, phone, mob_phone, bio fields can be changed using the following APIs set.

    i. Request structure

    (URL: PUT|PATCH /api/myself/)

The "Request" body should contain new values for writable fields related to users` representation. The PUT request involves full update, so all writable fields must be included into the request body. On the other hand, the PATCH request involves partial update, so you can omit fields that are not required to be updated. Moreover, the Read-only fields are ignored.

    ii. Response structure

In case of bad data are passed through, a standard validation error is returned. If a user is not authenticated, then a standard "not authenticated" error is returned. If everything is OK, a server returns HTTP code 200 and an updated representation of a user in full form will be includes (not only the writable fields).

    iii. Password change

This API is intended to be used when a user remembers his/her password, although the user should have a plan to change it. Further, it is important to note that this API will change user's authentication token.

    iv. Request structure

In order to request, we should use the following (URL: POST /api/myself/change_password/)

```
{

    "current_password": "qwerty",

    "new_password": "YouWillNeverGuessMe"

}
```

v. Response structure

In case the response is a success, the HTTP code will be 200 and the response body will be as follows:

```
{"token": "new auth token value"}
```

Now the user's password is set to a value of "new_password" field. In case of mismatch of current password, the HTTP code will be 400 and the response body will be:

```
{

    "detail": "Current password is incorrect."

}
```

Password Recovery

There are two APIs come under the password recovery: 1) apply for a password recovery; 2) confirm a password recovery.

To apply for a password recovery, a user should specify his/her username. Then the system will look for the user with this specified username by looking whether or not this user has an email. If the user exists and has an email, the system will then generate a new password and will send an email to the user. If the user does not exist or does not have an email, then the server will respond with the corresponding error message. Usually, once the password is sent by email, then this email will contain a new password and a link for confirmation. The new password will only become active, when the user follows the activation link. Also, the activation link will have 24 hours duration before it gets expired.

Moreover, the activation link consists of a recovery token, which will lead to a page in a front-end site. This page should send confirmation request to the corresponding API. The main goals of this solution are to get rid of redirects, achieve better user experience, and allow to integrate confirmation page into front-end projects.

So, the scenario for password recovery is organised as follows:

i. A user sends request "apply for password recovery" along with his/her username.

ii. A server checks if the user exists and has an email. In case of fail returns error, the end.

iii. The server creates a new random password and a confirmation token.

iv. The server builds the link and the confirmation page by pattern "/?token=

v. The server sends the new password and the link to the user's email.

vi. The user receives the email with the generated password and a link, which directs the user into the confirmation page.

vii. The confirmation page is a page of the front-end project. It takes the specified token from the query parameter and sends the request "confirm the password recovery" with the corresponding token.

viii. The server checks if the token still exists and it is not expired. In case of fail returns error, the end.

ix. The server assigns the new password to the user and responds "ok, fine".

x. The user can log in with the password generated in the recovery email.

a. Password Recovery Application API
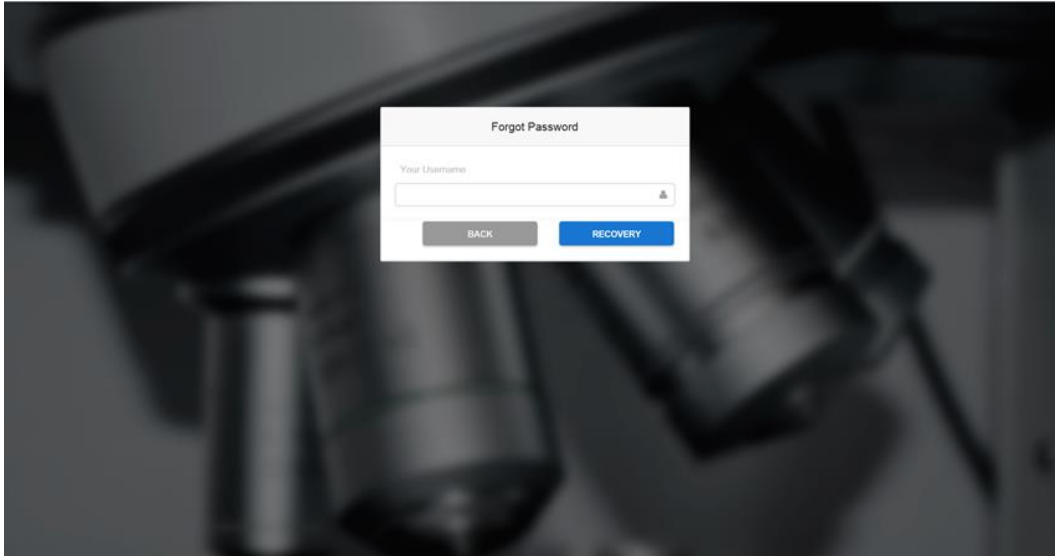
The above figure shows the password recovery screenshot.

(URL: /api/password-recovery/apply/)

The HTTP method related to this API is: POST. The Request of this body is represented as:

```
{

  "username": "example_user"

}
```

      i.   Response in case of any error:

The HTTP code related to this error is 400.

```
{

    "detail": "<< Error message >>"

}
```

The error messages could be:

- A user does not exist -> "Such user not found"

- A user exists but does not have an email -> "User does not have an email, so we cannot safely recover the password"
- A user has already applied for a password recovery and an activation token was not used nor expired -> "User has already applied for a password recovery"

ii. Successful response:

The HTTP code for a successful response is 200.

```
{

    "detail":    "Password    recovery    letter    was    sent    to    email
\"exam****.com\"."

}
```

b. Password recovery confirmation API

(URL: /api/password-recovery/confirm/)

The HTTP method for password recovery confirmation is POST. And the Request body is:

```
{

    "recovery_token": "22f79856-1902-430f-98be-2d9d11883ec9"

}
```

When there is a successful response, then the HTTP code is 200 and the response body is empty. However, if a token does not exist, expired or already used, then the server will respond with this HTTP code 400.

```
{

    "detail": "Recovery token is wrong"

}
```

Doctor Case

From the doctors or healthcare professional`s perspective or use case, there are implementations in the SAIF system that are listed in this section. For the doctors use case, the important aspect is the disease management functionalities. The implementations include the disease information module, categories, disease identification and link between the diseases. The implementation of these aspects is described below.

Diseases Management

The disease management module of the system includes seven entities: Diseases, Identifications, Categories, Recommendations, Treatments, Guidelines and Comments. Diseases and Identifications can be associated with each other using many-to-many relation (i.e., a disease can be identified by many identifications and an identification can be identified by many diseases). Diseases and Identifications can have a Category. A disease can have many Recommendations, Treatments, Guidelines and Comments, while each of them is related to exactly one Disease.

Disease can be represented in three forms: brief, detail and full. *Brief* representation contains only simple fields: uuid, scientific_name, name, description and category. *Detail* representation adds fields: num_comments and avg_rate, and lists related objects in fields: identifications, recommendations, treatments and guidelines. The related objects are represented by their IDs. The order of related objects is undefined, but it is stable.

The *Full* representation is as same as the detail representation, whereas the related objects are represented not only with their full representations but also with their IDs. The structure body of the related object representations is given in Appendix C.

Identification of the disease can also be represented in three forms: brief, detail and full. The difference between detail and full representations is as same as in the Diseases representation (i.e., the arrays of related objects turn into objects from just IDs).

The code implementation of the disease management system is provided in Appendix C. Below, the implementation of the disease management for the doctors is illustrated with screenshots from the SAIF portal.

4.3. Disease Management System

The *Diseases* section groups all the diseases from the SAIF system database into categories. Then, the categories give the list of diseases of such group in an alphabetical order each.

Managing the Diseases section

The Doctor will be able to create a disease section, define categories, and add information about the disease into the database. The procedure on SAIF portal is described below.

Creating a disease: To create a disease in the SAIF system the below steps need to be followed:

1. Select *Diseases* from the navigation sidebar.
2. Open the disease category and press *Add disease* from the upper-right corner.
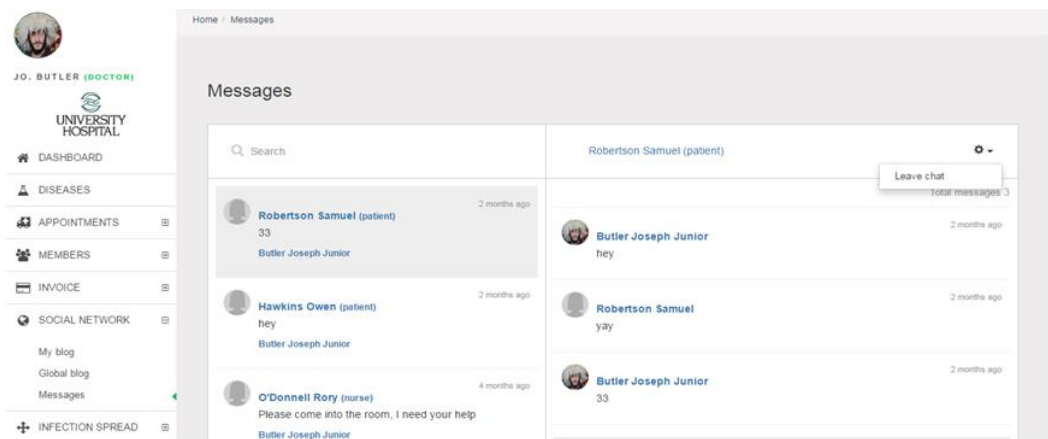
3. Next, fill in the disease description fields for the disease belonging to the category.
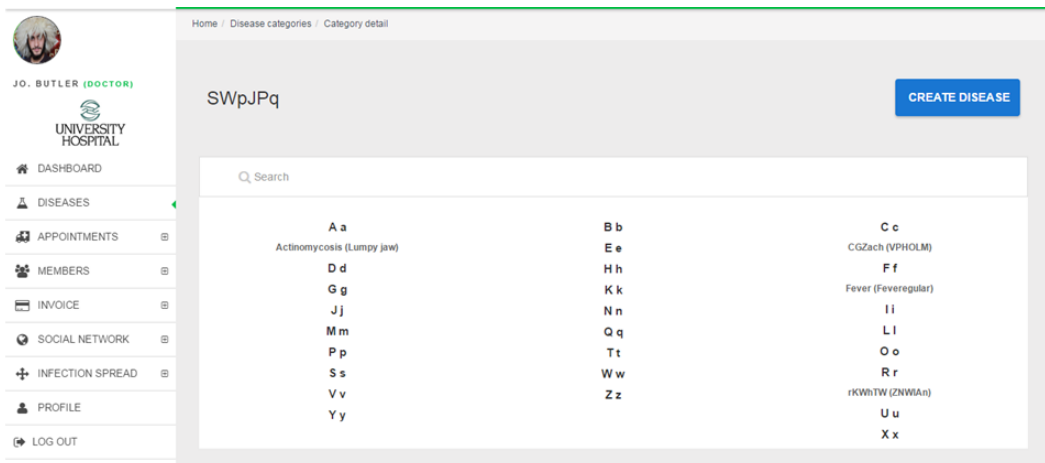
4. Press *Save* to add the disease into the MedOne database. Press *Back* to return to the diseases list.

5. Further, the doctor will be able to add description about the disease and the infection into the database for a given disease.
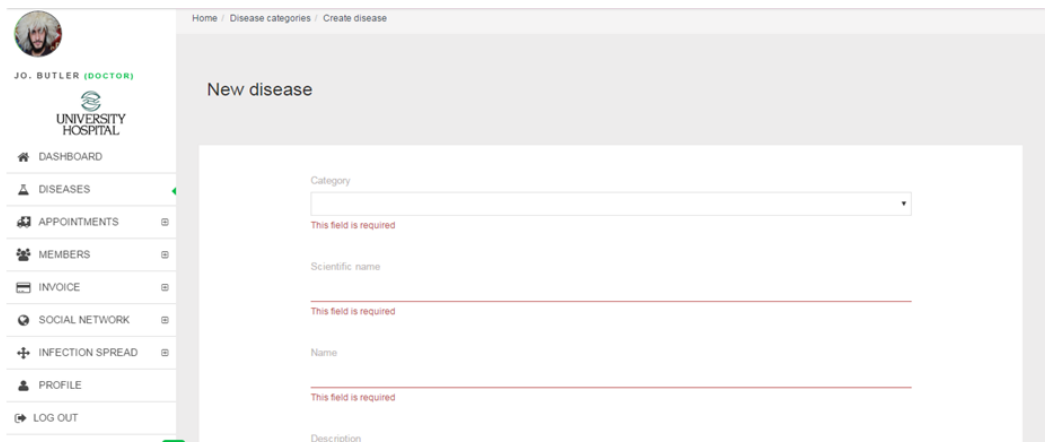
Other options such as editing the disease information, deleting information, and generating reports can also be performed by the doctor using the SAIF system. Details of the implementation of other entities such as Categories, Recommendations, Treatments, Guidelines and Comments are provided in Appendix C.

Below the information related to the API of some of the entities are provided below.

4.3.1. Diseases API

a. Create disease

In order to create a disease, we should use the following: (POST /api/diseases/). Then it accepts the following fields: scientific_name, name, description, category. Furthermore, the Category should be a UUID of the desired category. After the above is completed, then it returns the following: single detail representation (not full, exactly the detail view). This particular option is available for doctors and admins.

b. Update disease

In order to update a disease, we should use the following: (PUT|PATCH /api/diseases/<uuid>/). Then it accepts the following fields: scientific_name, name, description, category. It is important to note that the category should be a UUID of the desired one. When a PATCH method is used, any field can be omitted. Finally, it returns the following: Returns: single detail representation). This option is available for doctors and admins.

c. Delete disease

In order to delete a disease, we should use the following (DELETE /api/diseases/<uuid>/). When using the Delete method, then this deletes the disease and all the following information: links with identifications, comments, recommendations, guidelines and treatments.

d. Read one disease

In order to read one disease, the following is used (GET /api/disease/<uuid>/). During the return phase, it Returns single detail representation of the disease. Category is represented as an object with a name and a UUID. We can also use a Query parameter: full=t, thus it will turn representation of the disease from detail to full. It allows to include brief representations of related objects into response rather than of just UUIDs of this object.

e. Read list of diseases

In order to read list of diseases, then we should use the following (GET /api/disease/). So this will return the following: Returns list of brief representations of diseases. Also, categories are represented as an object with name and UUID. The Brief representation consists of these fields: uuid, name, scientific_name, description and category. The other fields (num_comments, avg_rate, identifications, recommendations, treatments and guidelines) are selectable. The following query parameters are essential to be defined:

name: This will filter diseases by name or scientific name. Now Diseases will match this filter, if at least one of the names contains value of this parameter. Hence, this parameter is case insensitive.

category: This will return only diseases that belong to a specified category. It will accept the category UUID.

identifications: This will include comma separated list of identifications UUIDs. Only diseases that relate to all of listed identifications will be selected.

This API is represented in the following figure.
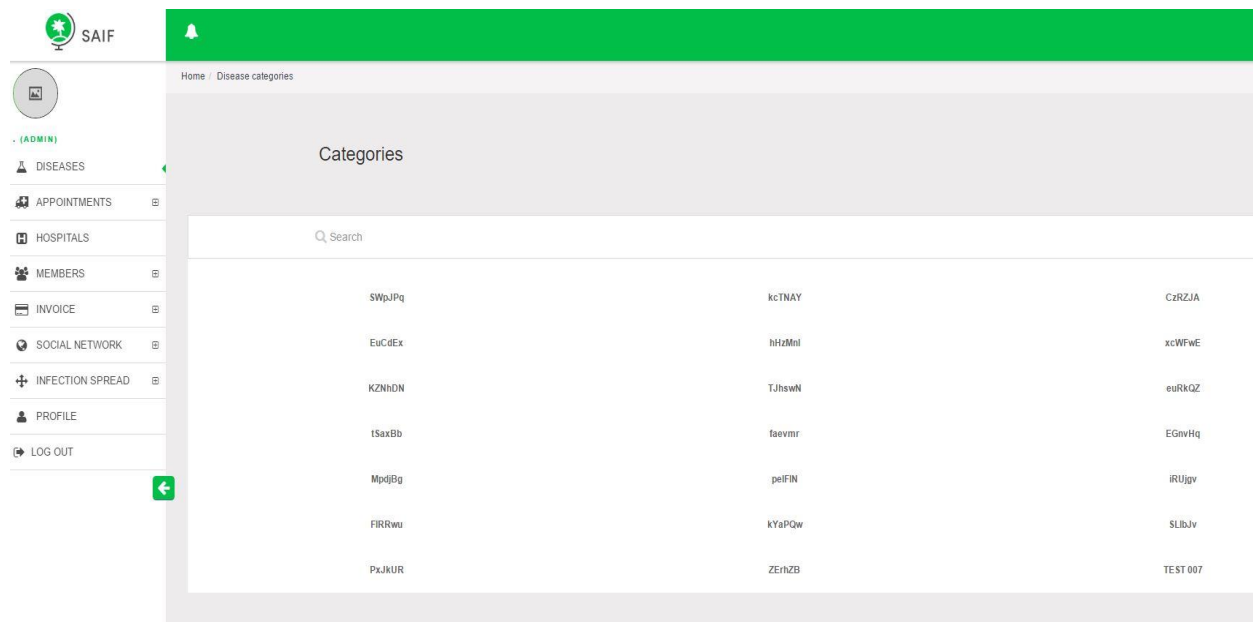
4.3.2. Identifications API

a. Create identification

In order to create an identification, we should use the following (POST /api/ identifications /). Then it accepts the following fields: name, description, category. Furthermore, the Category should be a UUID of the desired category. After the above is completed, then it returns: single detail representation (not full, exactly the detail view). This particular option is available for doctors and admins.

b. Update identification

In order to update an identification, we should use the following (PUT|PATCH /api/ identifications /<uuid>/). It is important to note that the category should be a UUID of the desired one. When a PATCH method is used, any field can be omitted. Finally, it returns the following: Returns: single detail representation). This option is available for doctors and admins.

c. Delete identification

In order to delete an identification, we should use the following (DELETE /api/ identifications /<uuid>/). This deletes the identification and all its links with diseases.

d. Read one identification

In order to read one identification, the following is used (GET /api/ identification /<uuid>/). Then it Returns single detail representation of the identification. Category is represented as an object with a name and a UUID. We can also use a Query parameter: full=t, thus it will turn representation of the disease from detail to full. It allows to include brief representations of related diseases into response rather than of just UUIDs of this object.

e. Read list of identifications

In order to read list of identifications, then we should use the following (GET /api/ identifications /). So this will return the following: Returns list of brief representations of diseases. Also, categories are represented as an object with name and UUID. The Brief representation consists of these fields: uuid, name, scientific_name, description and category.

The following query parameters are essential to be defined:

name: This will filter identifications by name or scientific name. This parameter is case insensitive.

category: This will return only identifications that belong to a specified category. It will accept the category UUID.

disease: This will return only identifications that are related to specified disease. Then it accepts the disease UUID.

4.3.3. Linking between diseases and identifications

    a.   Create link

In order to create a link, we should use the following (POST /api/ ident-links /). This creates a relation between disease and identification. After this is achieved, the identification will appear in disease's detail representation, and vice versa. This is available for doctors and admins. The request structure is written as follows:

```
{

 "disease": "UUID of disease",

    "Identification": "UUID of identification",

}
```

And then the response structure is written as follows:

```
{

    "uuid": "UUID of created link",
```

```
    "disease": "UUID of disease",

    "Identification": "UUID of identification",

}
```

b. Destroy link

In order to destroy a link, we should use the following (DELETE /api/ident-links/<uuid>/). The UUID in URL identifies the link and can be retrieved in three ways:

- Via diseases detail representation: from field uuid in objects of array under field identifications.
- Via identifications detail representation: from field uuid in objects of array under field related_diseases.
- When creating the link: field uuid in server response contains the link identifier.

This is only available for admins.

4.3.4. Categories API

There are two types of categories: disease category and identification category. Both category types are the same: they consist of name and identifier. Name is unique within a category type. Identifiers are intended to specify the category in URL instead of specifying it by urlencoded name. Also this allows to rename a category by keeping its identity.

There is a standard set of RESTful CRUD operations. All of them use the category representation described in Representations of diseases and related entities detailed above. Both fields (*uuid* and *name*) are included in list and single instance representations. Single instance access is utilised for the renaming categories. Reading and searching is available to all users. Creating, editing and deleting are available only for Admins. The details of the Categories API function codes are provided in Appendix C.

4.3.5. Appointments API

The appointments management system is an important feature of the SAIF portal. The doctors, patients, and nurses will be able to manage their appointments via the user interface. The process of appointment management is illustrated in the figures below.

1) Appointment information

The doctor will be able to view the list of appointments they have with details of the patient related information such as their name, Sex, Age, and other relevant details. This is shown in the figure below.
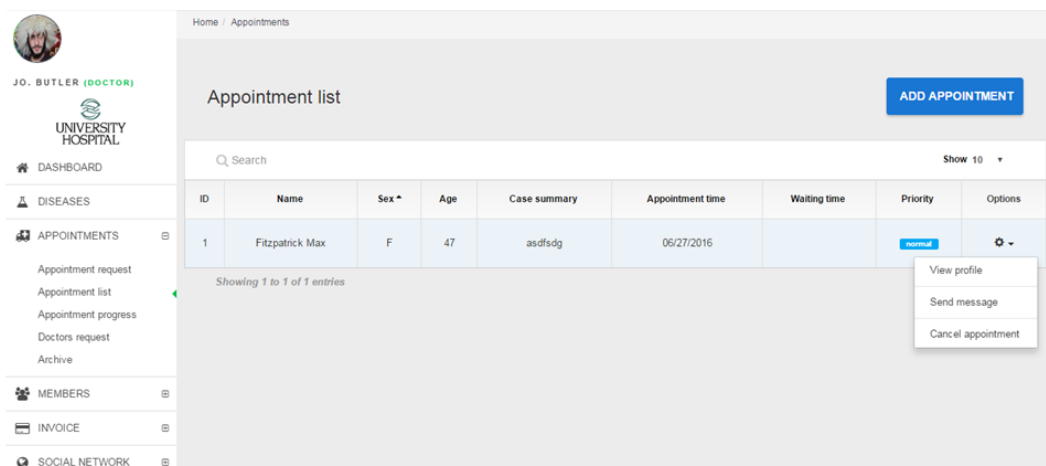
2) Appointee information

From the user interface, viewing just the appointments is not sufficient as they provide limited information to the doctor to prepare for the patient. The doctor will be able to view more detailed information about the patient and their profile from the 'options' tab in the portal. Further, the patients will be able to request appointment with the doctor. Such appointment requests can be viewed on the portal by the doctors.

3) Add appointments

Further, along with viewing the appointment requests from the patients, the doctors will be able to add appointments into their diary. This can be done by using the 'Add appointment' option on the portal and the doctor then adds relevant details including selecting a patient from the patient profile database, choosing the dates, and adding notes to it.
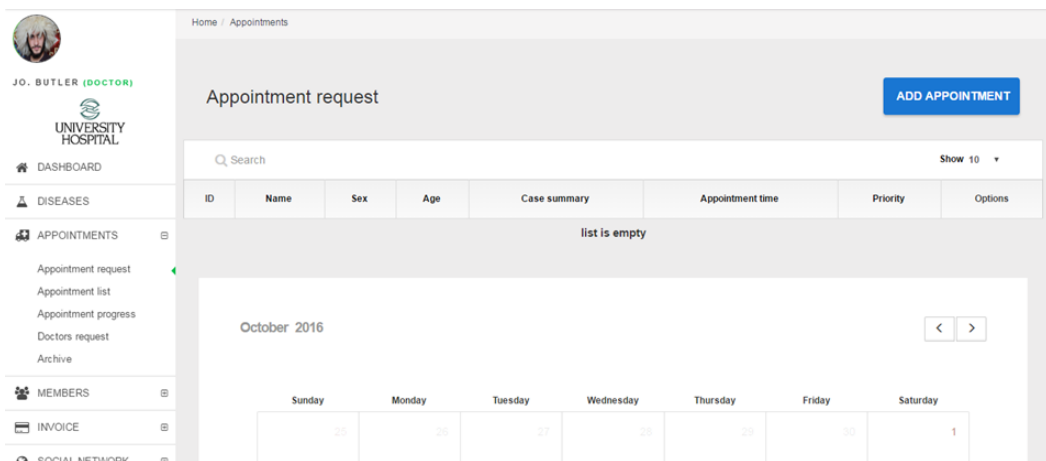
The appointments API implementation in terms of the codes and the REST API used is described in Appendix C.

4.3.6. Medications listing

GET /api/medications/ command is used to fetch the list of medications. This returns list of medications. The query parameters '**q'** will be used to make a query for a search by name.

4.3.7. Consultation Report API

This API is available for assignee doctor of appointment, admins and supervisor doctors. This API is implemented using the API call:

POST /api/appointment/<uuid>/report

If a report is already available, then this API becomes available for admins and supervisor doctors. If appointment is already closed, then this API becomes unavailable for assignee doctor. This API creates consultation report (that turns appointment to "in-progress" state) and allows to close appointment (move it to the archive). If a current user is admin or supervisor, then it allows to update text fields such as medical_history and treatment.

4.3.8. Writable fields

If a report does not exist yet, or if a current user is an admin or a supervisor doctor (no matter whether or not a report exists), then the following fields are used: *medical_history*, *examination*, *diagnosis*, *treatment*, *diagnosis_report*, *other_disease*, *prescription*, *disease*, *close*. If a report already exists and a current user is assignee doctor, then the following fields are used: *prescription*, *close*, *disease*.

4.3.9. Corrections API

Further, the doctors will be able to insert and update commands into the portal. This process is explained below.

   a. Create correction

POST /api/appointment/<appointment uuid>/report/corrections

This API is available for any doctor, when a report is created and an appointment is not closed. The following fields are writable: *target*, *data*. The target is a name of a field with correction applied. This API also creates one correction for the specified field of a report.

   b. Update correction

PUT|PATCH /api/appointment/<appointment uuid>/report/corrections/<uuid>

This API is available for admins and supervisor doctors, when a report is not created. Also, it allows to edit corrections. The writable fields are as same as the creation API.

4.3.10. Attachments API

This API is available for Doctors and Nurses. The target appointment must be *new* or *in-progress*. *Closed* appointments are considered unavailable. The creation and deletion of attachments is explained below.

   a. Create

   POST /api/appointments/<appointment uuid>/attachments/

This API accepts multipart-encoded data with two fields: *file* and *description*. The *field* file should contain the uploaded file itself. The field *description* is optional and defaults to empty string. Then it returns representation of created attachment. The file names are unique per appointment, so a server may return error (400) if there is a file with the same name.

   b. Delete

DELETE /api/appointments/<appointment uuid>/attachments/<attachment uuid>/

This API deletes the attachment.

4.4. Patient Case

Patient is an important stakeholder of the medical service. On SAIF, patient can create/edit/delete profile, accept/create appointments with a specified or unspecified doctor. Patient can get/send messages and posts inside the system. Patient can receive invoices and send feedback.

4.4.1 Function one: Logging in and out

i) Logging in

As soon as the patient opens the SAIF project link in a browser they need to include their credentials in order to login to the system. The user enters the username ID as email or user name, enters password, and then clicks on the Sign In

In case the patient forgets the password, they shall be able to recover the password using the password recovery mechanism described previously.

4.4.2 Patient profile management

Each patient will have an account that at which they can access and manage their profile. The two main functionalities in profile management page are the editing profile and changing password.

Editing profile

The patient can edit their profile details using the *Edit Profile* button at the top right corner of the page. At this page, they shall be able to fill in their information such as name, address, contact details, and biographical data. They also have options to include their profile pics.
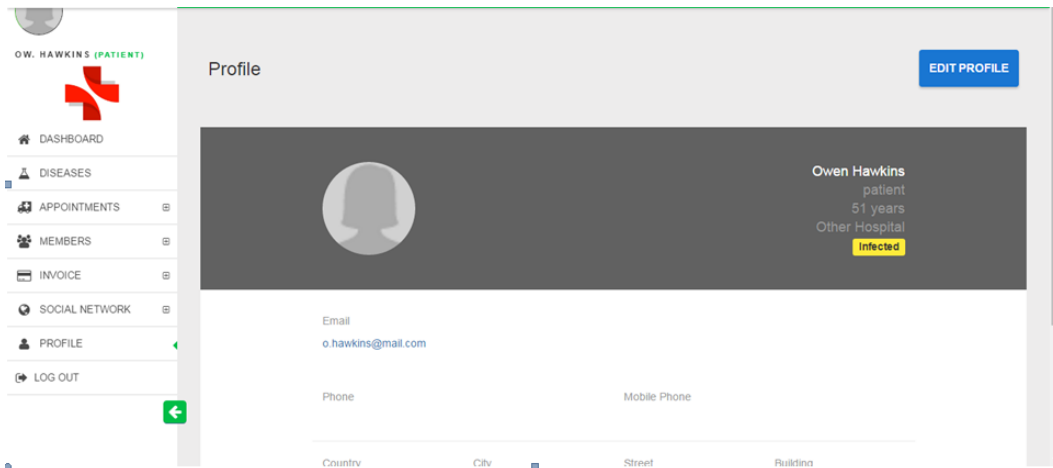
Changing Password

In the edit profile page the patient users of SAIF portal, will also have option of change password as shown in the figure below. To change the password, the standard three mandatory fields: *password, new password,* and *repeat password* must be filled in by the patients. It is illustrated in the screenshot below.
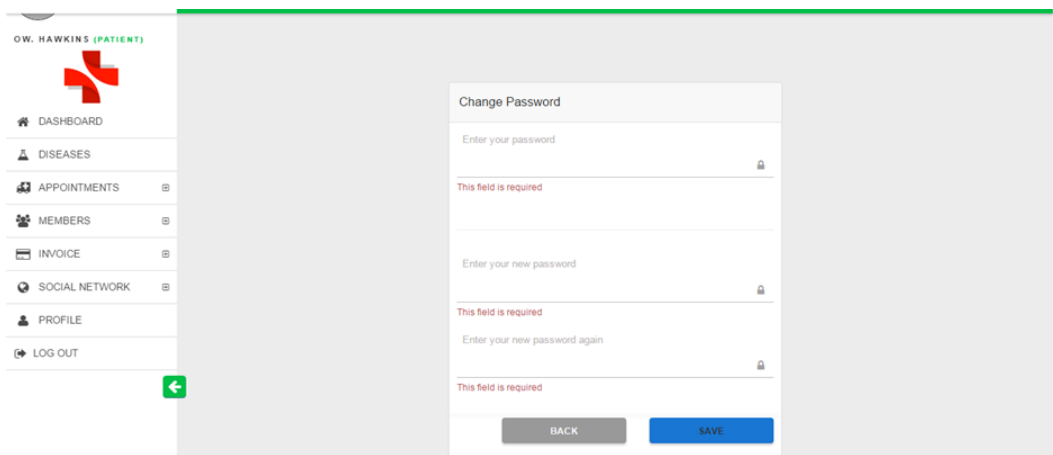
4.4.3 Viewing Members information

The patient would like to know information about doctors, nurses, and other staff in the portal. Every member such as doctor and nurses enlist their pages on to the portal. The patient can access the member`s information such as contact details including sending messages. The page to manage this is presented below.

4.4.4 Appointment managements

Similar to the appointments management page for doctors, the patients also have an appointment management page. At this page, they can add appointments, request for an appointment, view pending appointments, and also view the list of their appointments. The appointments page screenshot is provided below. The other functionalities for the patient page is similar to the descriptions provided in the doctor case.

4.4.5 Social Network

Patients are an integral part of the SAIF social network. The patients can read, comment, and share the blog posts. The page displays the list of the blogs where the patients can also view the most popular blogs on the portal. The *Leave comment* option allows the user to click on the post and leave a comment.
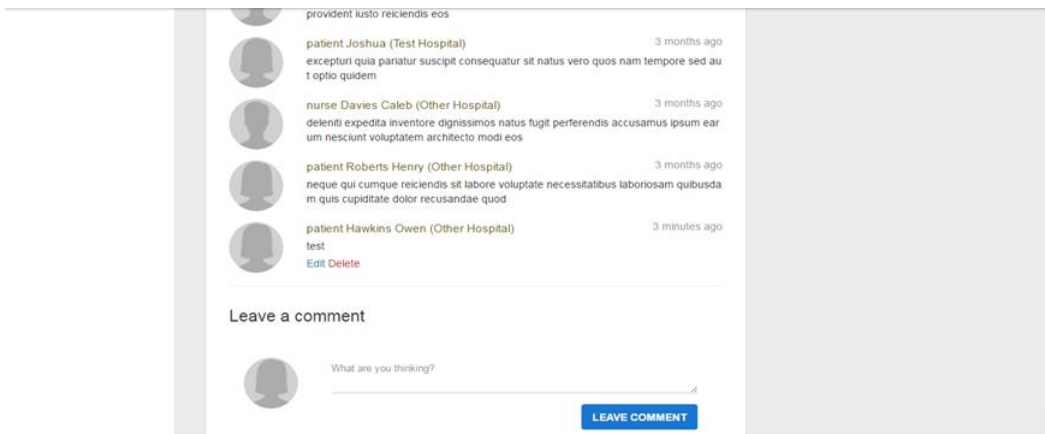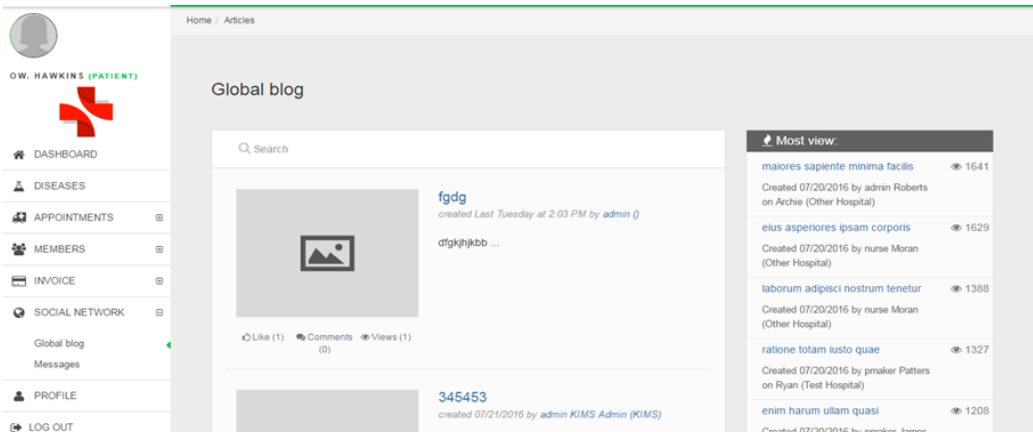
The SAIF system also allows the members to communicate between members. The patients can message with two options: via the social network and through the members list. They can send messages or also have live chat with the members through it as shown below.
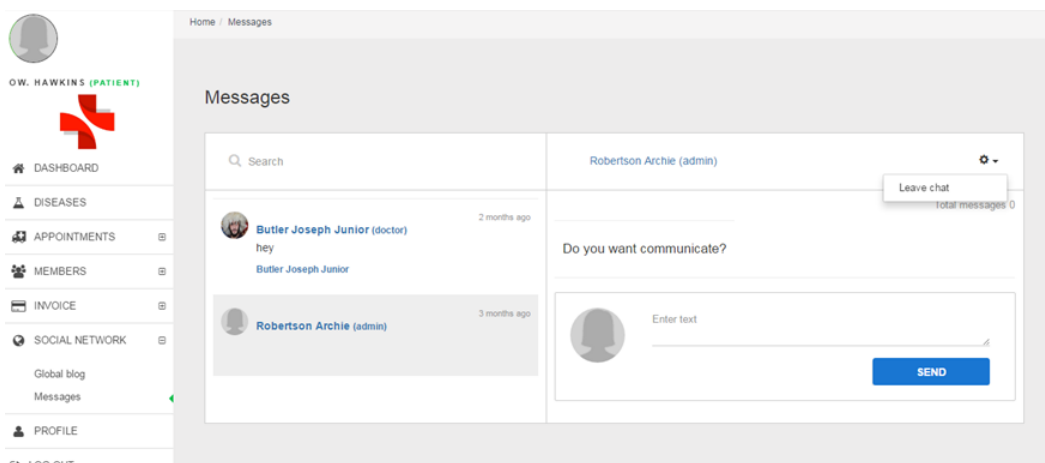
4.4.6 Disease Information

Possibly the most important functionality for the patients is to obtain information about the diseases. On SAIF system, the diseases are grouped into different categories. The categories then give the list of the diseases of the group in alphabetical order.

To find information related to a particular disease, the patient needs to:

1. Select the Diseases from the navigation sidebar.
2. Choose the disease category and find the disease from the alphabetical list.
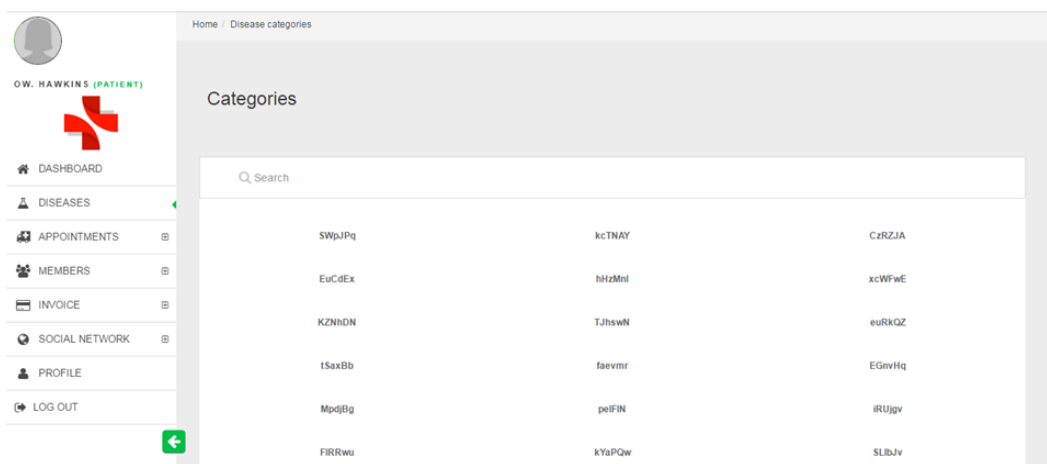
The disease information page gives information about the disease description, guidelines, symptoms, recommendations, and treatment as shown below.
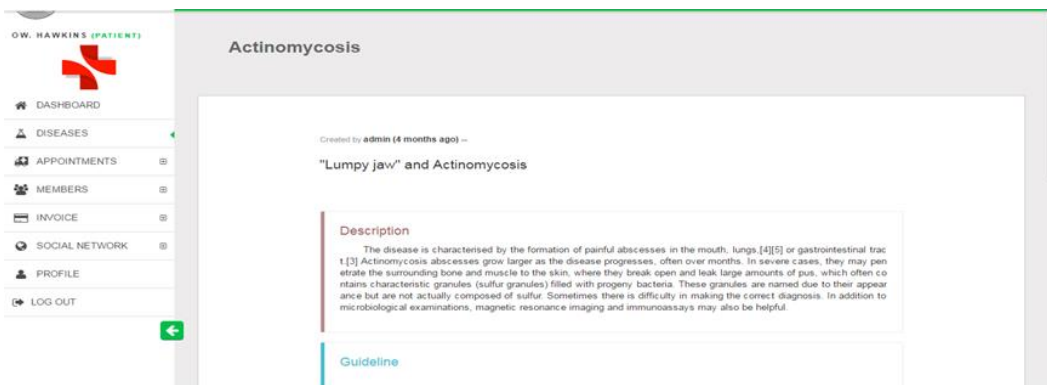
Policy Maker

The policy maker is a stakeholder who would use the information that are gathered from the SAIF portal. It gathers statistics from the map page, create or comment posts, and comment

on diseases. The policy maker also has similar functionalities as the patient or doctor profile. They also have credentials that are required to login to the system. The policymakers can also create profiles similar to doctor or patients, manage social networks, and also view disease information.

The important feature for the policymakers is the *Infection spread section.* In this section, the policy maker can follow the information about the infection spread which is processed and updated in real time.

i)   Map

One way for the policy maker to analyse the information is using the display on the map. The following steps need to be executed to follow the infection spread. They include:

a) Type in the disease name in the field using the selections provided from the database

b) Type the city name to zone in on a particular city

c) Select any specific patient demographics if required such as patient age or gender

d) Finally, click on *Sort* option to view the infection spread

The map is interactive for the user to analyse the spread in detail.
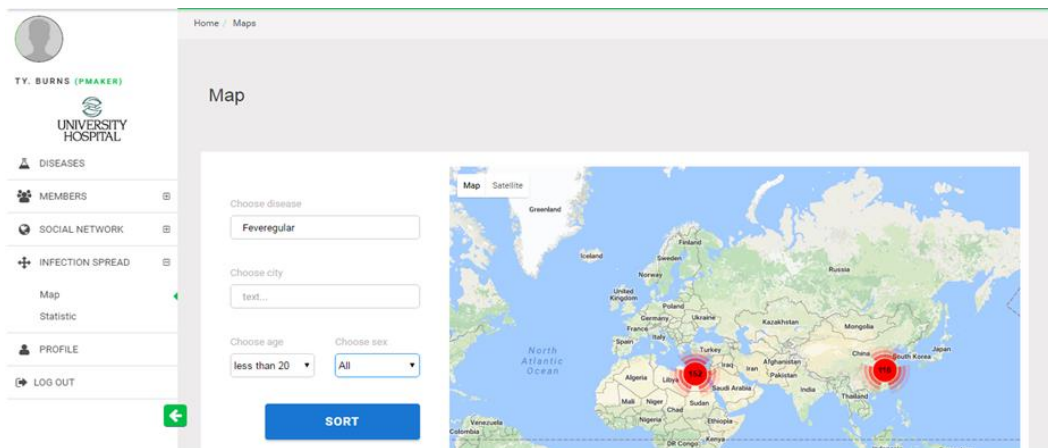
ii)   Statistics

Another option for the policymaker to get information is statistical information. To update the statistical information, do the following:

a) Type in the disease name in the field using the selections provided from the database

b) Type the city name to zone in on a particular city

c) Select any specific patient demographics if required such as patient age or gender

d) Finally, click on *Update* option to view analytics

The screen then displays various graphs and other related statistical information for the policymaker to better understand the scenario and analyse it further to assist in policy making.
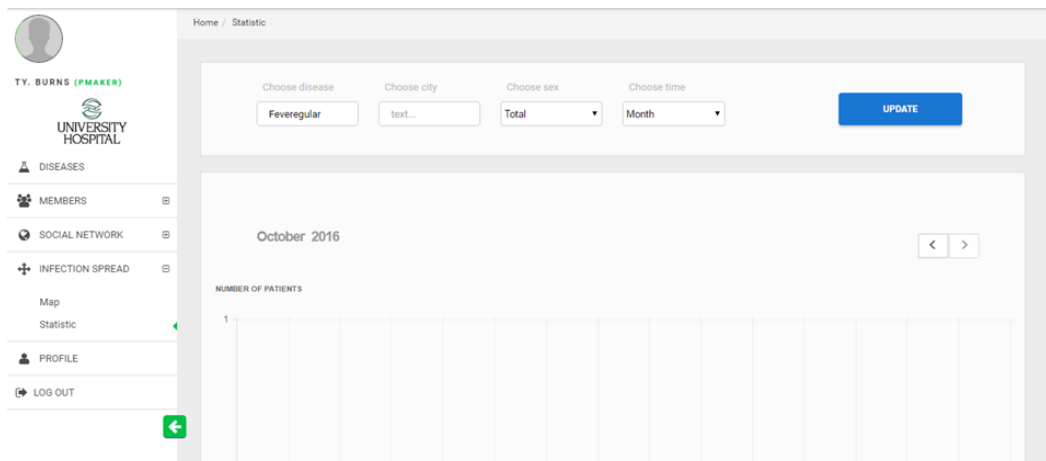
4.5. Framework Testing

In this section we continue the second part of this chapter. This section includes an introduction about the testing method used to examine the performance of the SAIF framework (so-called the black-box). It also includes two reports produced from the performed testing for two different software versions, where the first test reports the performance of the framework over a web browser and the second test reports the performance of the software over a mobile platform.

Black-box Testing Overview

The black-box testing is defined as a method to perform software testing through examining the functionality of an application without digging into the deep details of the software structure or its functioning. This testing method is applicable to perform testing over different levels of a software such as: unit, integration, system, and acceptance. The testing mostly includes high level testing [105].

The test procedures of the black-box testing is achieved as follows:

a) Certain knowledge of the codes in an application and programming knowledge in general is not required;

b) The tester should be aware of what the software is supposed to do, but not necessarily to be aware of how it does it (i.e., the tester should be aware that a particular input should return a particular output, but not necessarily required to know how the software produces the output).

SAIF Testing and Results

This section includes discussions about the performance of the SAIF software over: 1) most recent browsers; 2) and most recent mobile platforms.

SAIF performance results over a browser

We will initially report the summary of the first set of results, then it will be followed with detailed results. The results have been taken as screenshots and they are analysed / commented where necessary.
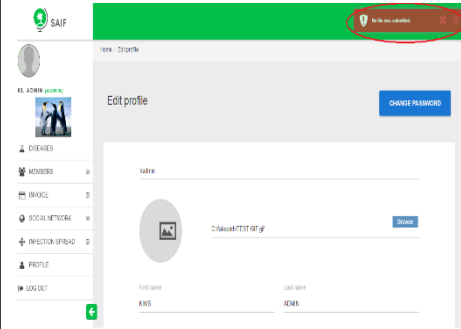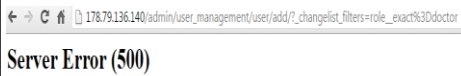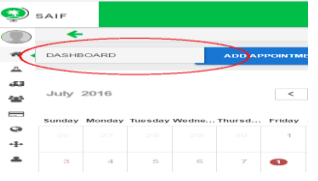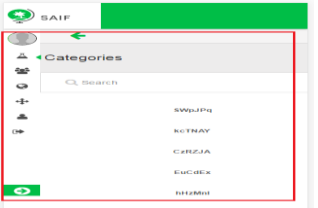
Browser Test Summary

The summary below represents the number of total defects obtained, the number of OPEN, PASS and FAIL status obtained while running the test over a browser by different roles. The parameters in the table are used to define the testing of the system via the black box testing method. The system is tested by developers, and the performance of the test is measured based on the Total defects, OPEN, PASS, and FAIL. The total defect indicates the number of bugs in the system. The open indicates the number of opened cases that will be tested. The pass and fail can be explained as examples. For instance, if "add patient" is an open case which could pass if a user is able to add a patient, whereas this case can fail if a user can not add a patient.

Browser Test Summary				
S.NO	**Total Defects**	**OPEN**	**PASS**	**FAIL**
1	66	16	50	0
   	Failed to reproduce			
   	Feature of the application			
   	Fixed			

Test Results

The test results include detailed analyses of the testing phase over a browser, where 66 tests have been performed by considering different SAIF's roles. Moreover, we included next to each test a description, the role chosen for the test, the status of the test, and a screenshot of the software at every stage. Since there are lots of testing performed on the system, we will report few cases which cover / comprehend most of the cases done across the software.

S.No		Description	Role	Status	Screenshot	Comments
1	Admin	Not able to upload Hospital admin profile picture and the following given error getting display in edit profile page <u>Error:</u> No files was submitted	Admin	**PASS**		
7		Server error getting display when we create new doctor for KIMS hospital via super admin (не смог повторить)	Super admin	**PASS**	178.79.136.140/admin/user_management/user/add/?_changelist_filters=role_exact%3Ddoctor Server Error (500)	

| 13 | Doctor | If Doctor add appointment via dashboard and open that appointment from dashboard and click on "save appointment" button then error getting display and there is no information for user which fields should not null | Doctor | **PASS** | | |
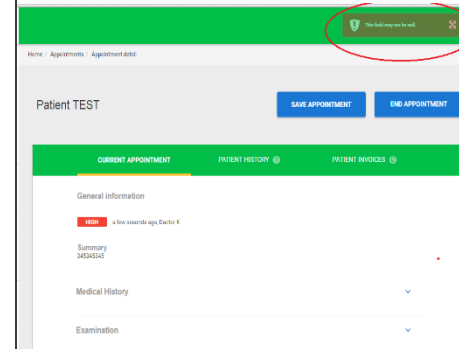
34		No validation message for "Choose patient/Choose doctor" field in Add appointment page, If user add appointment without selecting these fields error getting display	Nurse	**OPEN**		QA Comment: No validation message for "Choose doctor" field and without doctor appointment getting created
		Server error getting display on dashboard page		**PASS**		
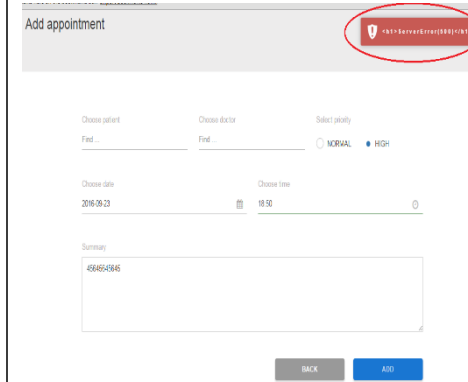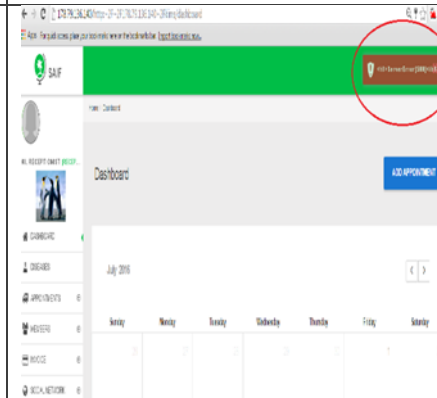
	Patient	If we add new appointment then newly added appointment not displaying on dashboard calendar and Appointment list grid		OPEN		

| 48 | Policy maker | Error getting display when we click on sort button in map view | Policy maker | **OPEN** | | QA Comment: Enter invalid data on "Choose disease/Choose city" fields and click on update button then error will display |
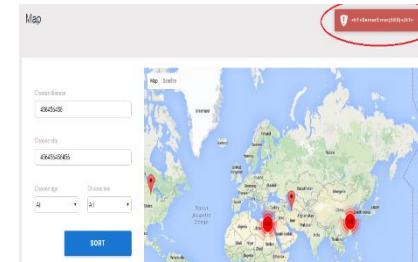
SAIF performance results over a mobile client

We will now report the summary of the first set of results performed over a mobile client, then it will be followed with detailed results. The results have been taken as screenshots and they are analysed / commented where necessary.

Mobile Client Test Summary

The summary below represents the number of total defects obtained, the number of OPEN, PASS and FAIL status obtained while running the test over a mobile client by different roles.

Mobile Client Test Summary				
S.NO	Total Defects	OPEN	PASS	FAIL
1	90	32	52	6

Test Results

The test results include detailed analyses of the testing phase over a mobile client platform, where 90 tests have been performed by considering different SAIF's roles. Moreover, we included next to each test a description, the role chosen for the test, the status of the test, and a screenshot of the software at every stage. Since there are lots of testing performed on the system, we will report few cases which cover / comprehend most of the cases done across the software.

S.No		Description	Device	Status	Screenshot	Comments
1	Admin	Edit profile button should display parallel to the profile title	iphone6	**PASS**		
6		If we enter more length in address field then it should display in second line	iphone6	**FAIL**		Entered test still not displaying in second line
65	Doctor	If we open "dashboard" menu from left side menu icons after opening the dashboard bash board menu option should be close and this issue exist for all menus	iphone6	**PASS**		
77		Add post button not fit to the screen	iphone6	**PASS**		
85	Policymaker	Diseases grid view design not good when we explore left side menu bar	iphone6	**OPEN**		

| 89 | Patient | Error getting display when we login to the application as patient | iphone6 | **OPEN** | | |

4.6. Conclusion

This chapter provided an overview over the implementation and testing of the SAIF project. This chapter aimed to manage infectious diseases, make use of the social network, and provide smart maps and statistics for the policy makers associated to the spread infectious diseases and patient status in an area. The implementation and testing conducted in this chapter was achieved over the current prototype version of the SAIF platform, including its services required for data collection, technical deployment of the platform, and a short guidance about the platform usage that navigates through some components.

In the next chapter, we will discuss the usability and adoption of the SAIF system in the kingdom of Saudi Arabia. This will include an introduction of the current state of e-heath in KSA and government trends in adopting e-services in health, a conceptual model for identifying E-health System Evaluation Criteria (ESEC), and an evaluation of SAIF will be represented with results analysis.

Chapter 5: Usability Study of SAIF System

5.1. Introduction

Citizens of developing countries do not receive a high level of healthcare quality from E-services, including e-health, which is generally characterized by a lack of user involvement in the development process. This chapter introduces a comprehensive evaluation for the usability acceptance and the adoption of the e-health service system SAIF in KSA, which is based on user experience. This chapter evaluates key factors in user experience that affect the usability, acceptance and adoption (UAA) of SAIF in KSA and the interaction of its social network blogs with e-health systems. The evaluation is based on a quantitative conceptual method in measuring the UAA criteria based on an existing literature review that focuses on e-health system evaluation criteria (ESEC). This evaluation accounts an experimental evaluation that is conducted through surveys or questionnaires in order to achieve the following aims: 1) to test empirically the ESEC variables and identifications sourced from existing literature as a solid instrument for evaluation requirements for the e-health system SAIF, and by depending on the comprehensive efficiency of the e-service delivery 2) to investigate perceptually the understanding and awareness of the users (patients and health staff) for the provided e-health services in KSA, and to recognise the user requirements that lead to more improvements through feedback and suggestions channel. The outcomes from both the empirical and perceptual investigations of the e-health system besides the findings from the existing knowledge are designed in this chapter as a validation measurement for SAIF system adoption, acceptance and use as an approved e-health management system in health sector organisations.

This chapter is structured as follows. The second section introduces the current state of e-heath in KSA and government trends in adopting e-services in health. The third section introduces a conceptual model for identifying ESEC. The evaluation of SAIF is represented in the fourth section, and the results are analysed in the fifth. Finally those sections are followed by the conclusions and summary.

5.2. E-health status in KSA

There are growing concerns regarding the under-utilisation of e-health in KSA, despite the adoption of e-health management systems having been applied by the Ministry of Health

(MOH) in the form of electronic information for patients. Several hospitals and health outpatients' clinics are adopting current scenarios for e-health systems, such as university hospitals, National Guard Health Affairs (NGHA), King Faisal Hospital and the Medical Services of the Army Forces and Research Centre [106].

Meanwhile, there is a slow process in adopting the e-health services by the government in the MOH organisations, partly because several IT services are used across MOH institutions, but the main problem is that they are not connected with each other with one portal or e-health system that enables the user to be connected though the whole system [107]. The MOH has allocated a budget of $1.1 billion (US) to develop the e-health systems in the health sectors through a four-year program [108]. A series of research conferences have been conducted in KSA in the e-health field and the methods of developing the e-health services in MOH research have focused on the development strategies, polices and necessary applications to build a solid infrastructure [109]. More coordination between e-health sector organisations is needed to develop a common electronic platform for e-health services and to enhance usability and acceptance for a comprehensive system of health services through the internet.

National E-health strategy in KSA

The MOH adopts an e-health system in order to improve the health care level in the health sector. The Ministry is achieving this vision and objectives by the concept of electronic health in KSA, which has been started to be implemented through a program that defines the characteristics of the e-health vision as "*safe, efficient health system, based on the care cantered on a patient, standard-oriented, and supported by the e-health*" [110]. The MOH launched its e-health program in 2011, and it has been in progress since then, undergoing two phases for e-transaction, each of which was scheduled to be finished before 2018 [110]. A road map was established for the program with several tasks and groups aiming to reach the e-health vision in the health sector. There are several challenges facing the project, particularly management issues and addressing the requirements from the MOH as part of the e-transformation in the whole governmental sections, but with consideration of the sensitivity of the programs as it deals with health issues and complaints from existing patients rather than general citizens [110]. There is widespread ambiguity about the aim of

excellent quality of health service in the MOH for patients and health staff through the concept of e-health [110].

E-Health Adoption Barriers

There is great possibility for adopting e-health systems as reliable systems in the health sector, but it would face several technical and management issues that are addressed by evaluation in this chapter. The barriers of adopting e-health system in KSA could be categorised into four sectors from the perspectives of citizens and IT specialists, as shown in   Figure 5.1 [111].
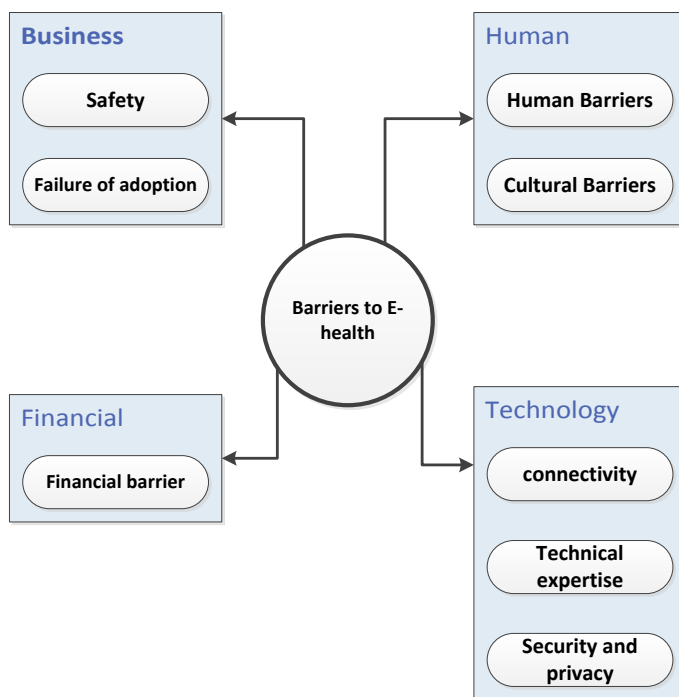
Figure 5.1: Elements of e-health barriers.

The e-health adoption barriers are concluded in the following points in general from clinical staff perspectives and concerns [111]:

- Lacking of personal control over the medical cases.
- Lack of confidence in dealing with new E-Systems due to low level of skills in computer and potential to learn new methods.

- The failure in recognising the value in e-health

- Having the anxiety and transparency in dealing with medical practices

- The link between the management and e-health users from clinical staff.

The e-health barriers from the patients' perspectives are listed as the following [111]:

- Lack of trust in the new e-health tools.

- Having concerns regarding being allocated with unknown medical staff.

- Lack of confidence in the replacing the real persons in the administrative staff with e-services such as e-booking.

- Concerns about limiting the choices of the utilities and medical services verities.

- Lack of trust in the online data protection and security of provided medical information.

E-health stakeholders

E-health involves the participation of several different stakeholders including state and private sector players, defined according to their ownership of e-service. The primary stakeholders in KSA are divided into receivers of e-health services, corporate partners and the governmental health sector.

5.3. Methodology for the measurement of E-health systems evaluation criteria (ESEC)

The research presented so far has investigated the e-health system management adoption in the previous chapters, which included the design and the requirements for e-services from technical criteria sides. This section introduces the conceptual basics that have been investigated to address the measurement criteria depending on the previous findings in the literature review and highlighting the key factors from previous technological studies in the field of e-services and Management Information Systems (MIS). The Information System Success Model (ISSM) [112] and the Technology Acceptance Model Version 3 (TAM3) [113] have been chosen to address and develop the usability, acceptance and adoption (UAA) of SAIF system and its effectiveness in KSA through studying the influence of different variables on adopting the e-system in order to meet the gap in the designed system

and the literature review, therefore the evaluation is done by taking into consideration the designed conceptual model for UAA, as shown in Figure 5.2.

The low adoption of e-services by employees in organisations is considered as one of the major obstacles in reaching and implementing a successful e-service [125]. The conceptual basic model illustrated in

is used to conduct the empirical pilot study in order to identify the level of quality and requirements in developing the e-health system SAIF. The user involvement from patients and doctors participated in providing validated feedback and suggestions, depending on their experience.

The conceptual model for measurement is built according to the basic key factors that are taken from the previous validated models ISSM and TAM3, beside the MIS found in the previous studies in literature review. SAIF system is used here as an illustrative example to test the e-health usability, adoption and acceptance in the Saudi health sector with the aim of using the empirical findings as general criteria for the features of an e-health system in a developing country.
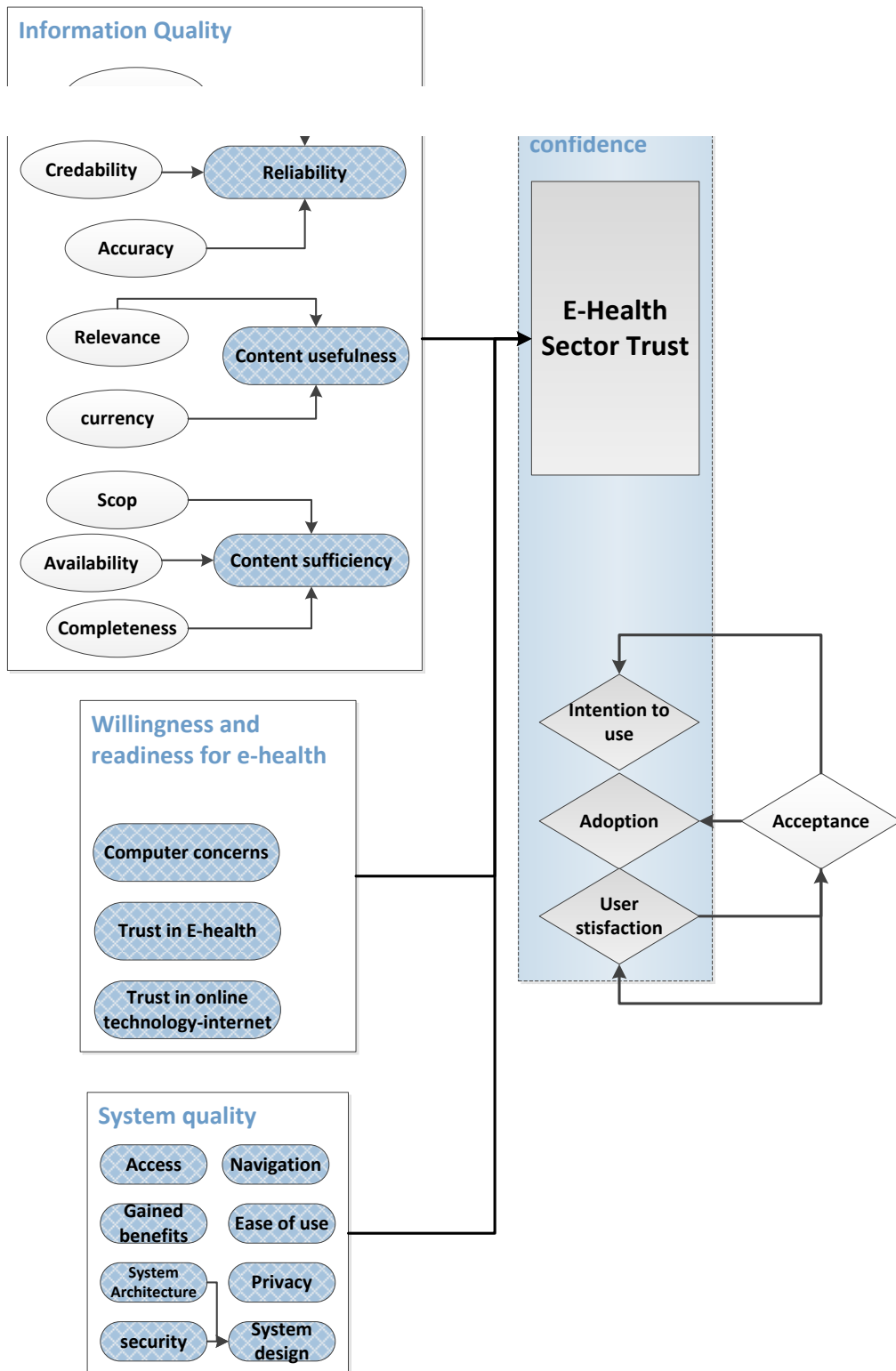
Figure 5.2 Validated Conceptual model for the evaluation of usability, acceptance and adoption (UAA) of SAIF system (validated by [112, 113]).
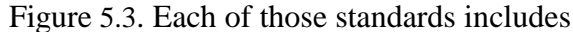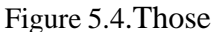
As shown in

Figure 5.2, there are four interrelated standards concerning the evaluation, adoption, acceptance, user satisfaction and intention to use the system. Moreover, there are three measurement variables that evaluate the three standards and contribute in the concept of e-service confidence: quality of system, overall quality of provided information, and willingness and readiness for e-health system. The four measurement variables consist of several main factors that affect the evaluation of measurement variables, such as content

usefulness and computer concerns. The main factors are affected by sub-factors such as system design and availability. The pilot study addresses this conceptual model for evaluation, which was validated and used by [112, 113]. The design of e-health system SAIF is based on the technical and functional requirements of patients and the preferences of physician's doctor's preferences in dealing with electronic services. Those requirements and specifications have been designed in the system SAIF and tested empirically for evaluation and validation purposes according to the main and sub-variables and factors listed in the conceptual evaluation model for an e-service.

Several previous evaluation models have been taken into consideration in designing the framework of the model for an e-service, such as the empirical study conducted by [114] for a developing and improving an e-commerce system, whereby acceptance was evaluated through a model called e-commerce technology acceptance model (ECTA). The authors in [114] provided a comprehensive model to clarify the link and the influence of the internal and external factors of e-commerce acceptance. The main factors in ECTA are adopted as variables by culture, and trust as a sociological effect.

Measurement standards

Four criteria are handled to illustrate this evaluation which their influence are linked with each other, as seen in   Figure 5.3. Each of those standards includes several factors that are interlinked with their influences, as seen in   Figure 5.4.Those factors are represented in several items for testing and evaluating purposes in order to validate the evaluation through the items of the questionnaire, which evaluates the standards taken from previous studies reflected in the variables. All the questionnaire items were evaluated with a seven-point Likert scale ranging from "strongly disagree" to "strongly agree". The last part of the questionnaire is designed in a different way, whereby the total information quality is tested over a scale called "semantic differential" whereby the scale is evaluated according to a seven-point scale between two contrasting pairs of words or adjectives that describe the total feedback for the overall all information quality. The participant is asked to evaluate the level of agreement with the pair of contrasted words by choosing the closest point in the scale between the two descried words. The evaluation is

done according to the following major measurement standards (see Figure 5.3):
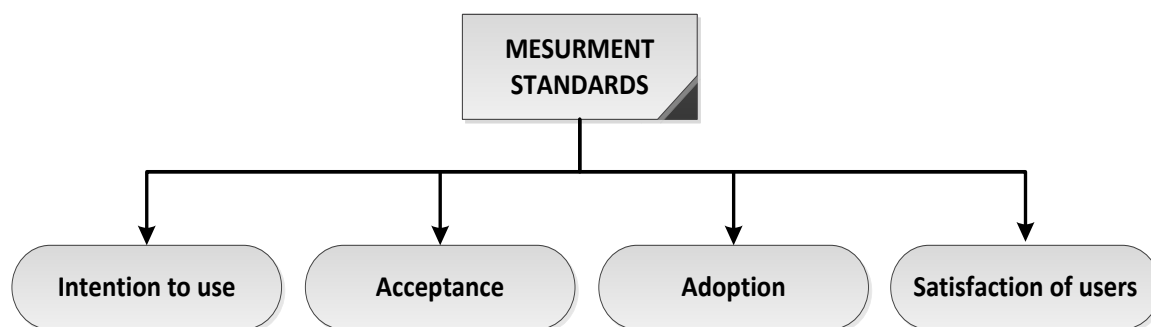
Figure 5.3 Major Measurement standards.

Satisfaction of users

User satisfaction is influenced by the quality of the system and overall information quality, whereby a low level of satisfaction is provided by a low level of quality and thus negatively affects the used system. Therefore, there is an obvious correlation between satisfaction and quality, according to which poor quality entails expectations of dissatisfaction [115]. Several studies prove the relationship between satisfaction and quality (e.g. [116, 117]), which provided an assessment process to test the correlations between the improvements in tested system such as usability and usefulness from one side and user satisfaction from the other.

Adoption

The satisfaction of the user is interlinked directly with willingness to adopt the provided system and the intention to use it over time; therefore, the improved satisfaction increases both adoption possibility and the intention to use [118]. The adoption is defined as the actual use of a service by the user, which is followed normally by the acceptance stage by users or adopters. The perceived importance of e-health system by adopters plays a vital role in increasing the possibility of adopting the provided e-health system SAIF. Therefore, the adoption standard is reflected by several concepts in evaluation such as usefulness of e-health by users, behavioural performance and user experience.

Acceptance

The stage of acceptance comes before the adoption step for the user. In order to determine the acceptance of a system several factors should be reached, such as user satisfaction, which is mutually linked with acceptance. Also, reaching the acceptance stage supports numerous possibilities. According to the theory of expectation confirmation, the concept of usability relies on a strong link between the acceptance part and the satisfaction usage [119]. [120] examined this relation by assessing the user experience based on quality and performance factors toward accepting a service or a product based already on the user satisfaction as a measurement scale for acceptance.

Intention to use:

The intention to use is based on user attitudes towards the product and their (perceived) need for the provided service, which pertains to the user expectations and requirements. Furthermore, it is based on the user perception for quality standards; therefore it is connected with user satisfaction, adoption and acceptance standards. Also there is an effect on intention to use by e-system trust, and usefulness of provided e-system [121].

Survey variables and associated features

The survey is divided into three sections according depending on the previous measurement standards, as shown in   Figure 5.4.
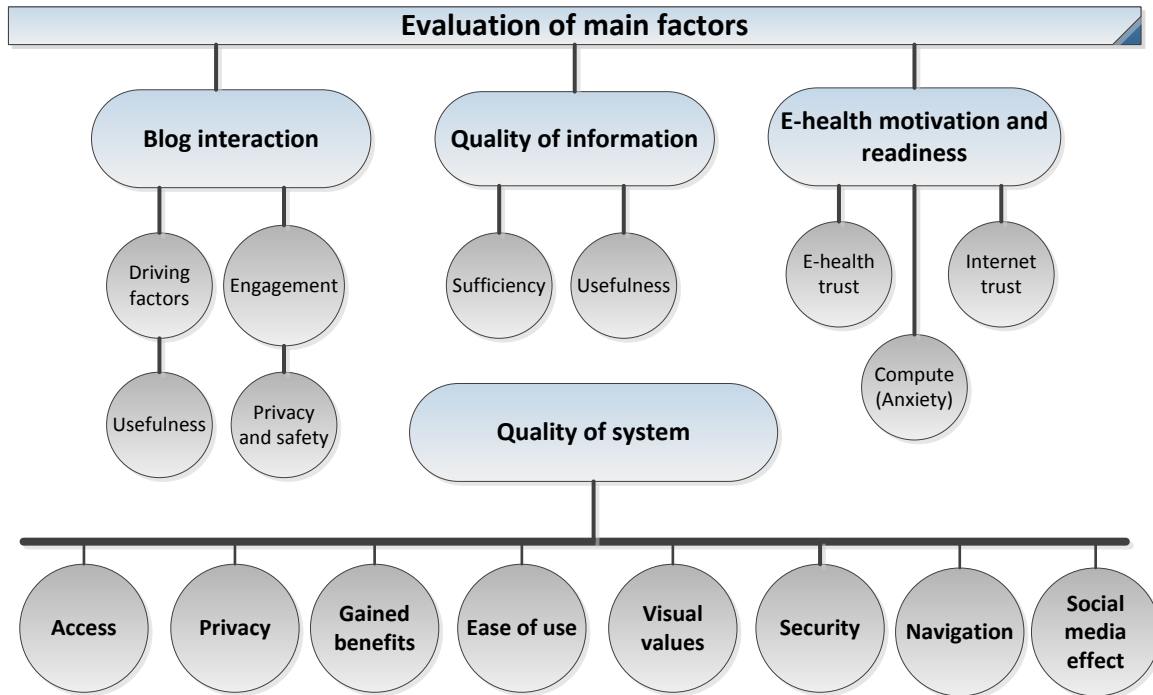
Figure 5.4 Categorised Survey variables and associated features.

Motivation and readiness for e-health

Motivation or readiness for e-system is defined according to the awareness of Information and Communications Technology (ICT) strategies depending on the level of access to IT structure and level of IT skills in a specific country. According to ranking by Economist Intelligence Unit (EIU) and International Business Machines (IBM) (2010), the readiness for e-services in KSA is 52. Depending on the conceptual model shown in Figure 5.2, the motivation and readiness is determined according to three factors; trust in e-health, internet trust and computer concerns. System trustworthiness plays a vital role in user demand, acceptance and requirements for e-systems [123], and it also has a strong effect on the intention to use [124].

Trust in e-health represents the level of confidence by the user in using as system that is provided by MOH or any health agency, while trust in the internet represents the level of user confidence in the online services in general and the level of acceptance for the e-applications over the access of internet [125]. Computer concern represents the level of anxiety associated with the use or interaction with computers rather than physical documents

and personal communication [126]; such anxiety has a big influence on the perceived ease of use concept for users [127].

Quality of the system

The quality standards refer to users' understanding and awareness of performance level of e-health system, which depends on user expectations and requirements. The outcome of this section in the survey depends mainly on the following items:

1. Ease of use, which reflects the user's ability to perform tasks over the system with less efforts and time [128], and by taking into account the strong relation between awareness of use and system quality [112];
2. Gained benefits, which reflects the perceived usefulness from using the e-system and the amount of useful outcomes that could be gained by starting using the new system [128].
3. Access, which represents the ability of the user to access the service depending on two factors; availability and responsibility, therefore the access level is determined by the users according to their access to the e-health system with website speed and all the time including off days [129].
4. Privacy and security, which reflects safety of dealing with e-health systems in terms of data protection principles and secure financial transactions, if applicable [129].
5. Navigation, which reflects the ease of moving between tabs and pages with an easy number of clicks in order to reach the required information of task [130].
6. Visual values and design, which include the way that contents are displayed in the system to present the information such as texts, images, videos and colours according to the subject of the system and the importance rank [131].

Quality of information

This dimension of quality depends on two main variables, the sufficiency and usefulness, which indicate the level of quality for the provided information in the e-health system [132]. Each of the two variables consists of several sub-measurement features pertaining to availability, reliability and accuracy. The quality of information provided by e-health is

classified as an important factor that affects the concept of trust in the MOH and its health agencies responsible for providing e-health systems, such as SAIF [133].

5.4. Pilot study for SAIF evaluation

The evaluation of SAIF was conducted depending on the conceptual model in the previous section using a pilot study that tests the variable of the study depending on measurement standards. The pilot study focuses mainly on the characteristics and requirements of SAIF services and how it affects the overall efficiency and usability of the system deliverables. One of the important aims of the e-health system is to provide useful information and ease the tasks of users (i.e. patients and health workers).

The pilot study was conducted in Saudi Arabia during June-July 2016, using a questionnaire for evaluation purposes (*Appendix A*) in order to collect quantitative data that are believed to have an influence on the usability, acceptance and adoption (QUAA) of the e-health system SAIF and the interaction of its social network blog with e-health system. The questionnaire was distributed depending on an empirical method, taking into consideration the end-user experience according to an ethical approval and illustrative factors (*Appendix A*).

Study Participants

The study was conducted with patients, doctors and receptionists in the health facilities displayed in   Table 5.1. The survey has been introduced to participants within the general ethics standards and by acknowledging the participants of his right in knowing the destination and the purpose of the study. The participants' answers were highly anonymous and confidential and was used for research purposes only whereby all the provided answers will remain entirely anonymous, the participant was informed that they have the right to withdraw at any time.

Table 5.1: Survived hospitals in KSA for SAIF evaluation.

Hospitals	*General practice centre GP*
NGHA Medical Centre in Saudi Arabia	General practice centre GP - AL MURABBA -AREA
King Fahad Armed Forces Hospital	General practice centre GP - AD DHUBBAT
King Faisal Armed Forces Hospital	General practice centre GP - AL MALAZ
King Khaled Hospital	General practice centre GP - AN NASIM AL GHARBI
King Saud Hospital	General practice centre GP - AN NASIM ASH SHARQI
King Fahad Hospital	General practice centre GP - AL KHALEEJ
	General practice centre GP - AL HAMRA

The study protocol was distributed as sample of 98 questionnaires (QUAA) for different areas and different users such as doctors, patients, nurses, and receptionists. 40 questionnaires were returned with completed valid responses. 12 were partially completed and collected, 8 were indicated as invalid and discarded. The QUAA was setup using seven-point Likert scales whereby the user was asked to perform several tasks depending on a given case study in order to be able to answer the QUAA. Each item of the QAAU was rated on a scale from 1-7, with additional answers provided in case of confusion or not applicable ('Do not know'). The demographic description of study participants is illustrated in Table 5.2.

Table 5.2: Demographic description of study participants

Variables descriptions		Number	Percentage
Gender	Female	22	42.3%
	Male	30	57.7%
Age group	18 to 24	5	9.6%
	25 to 34	12	23.1%
	35 to 44	12	23.1%
	45 to 55	15	28.8%
	55 +	8	15.4%
Level of education	Less than high school degree	5	9.6%
	High school degree or equivalent (e.g. GED)	8	15.4%
	Some college but no degree	9	17.3%
	Associate degree	3	5.8%
	Bachelor degree	19	36.5%
	Graduate degree	8	15.4%
Occupation	Senior Doctor	5	9.6%
	Junior Doctor	8	15.4%
	Receptionist	5	9.6%
	Patient	34	65.4%
Average of computer usage per day	less than 1 hour	5	9.6%
	1-3 hours	17	32.7%
	4-6 hours	11	21.2%
	+6 hours	19	36.5%
Skills in information technologies	Very low	4	7.7%
	Low	3	5.8%
	Medium	14	26.9%
	High	21	40.4%
	Very high	7	13.5%
	Don't know what IT is	3	5.8%

Pilot study tools

The questionnaire contains three main sections; the first section consists of seven items for demographical collection reason. The second section consists of tasks description for each participant depending on its occupation and role in order to undertake the questionnaire questions. The last part contains 78 items that evaluate the e-health system according to the major

measurement criteria that are mentioned in the previous sections and depending on the conceptual model that has been designed for the purpose of evaluation. The questionnaire items were collected according to previous research studies evaluating correspondent values and variables in e-systems and to serve the main concepts behind this evaluation, which are usability, acceptance and adoption (UAA) and social network interaction with patients/doctors. The studies shown in Table 5.3 were used to design the conceptual model shown in

Figure 5.2 and the questionnaire items (*Appendix A*).

Table 5.3: Studies main variables that are adapted from previous references

Questionnaire part	Correspondent references
Motivation and readiness for e-health system	[118], [123], [125], [127]
Quality of system	[59], [128], [130], [131], [132]
Quality of information	[112], [119], [130], [132]
Acceptance and adoption	[112], [113], [115], [118]

The questionnaires were adopted based on the previous studies' criteria, and all measurement items were evaluated based on the seven-point Likert scale varying from 1 ('Strongly disagree') to 7 ('Strongly agree'), and the quality of information was tested according to a differential scale whereby each pair of words shows contrasts on a scale of seven (Figure 5.5).
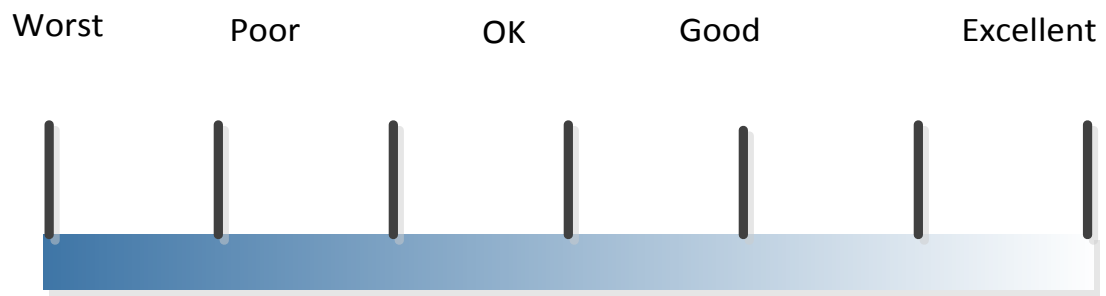
Figure 5.5 Calibration over 7 point Likert scale.

5.5. Results and discussions

Table 5.4: Mean, Standard deviation, confidence value and interval for QUAA questionnaire data.

No	Factors and variables	No. Items	Mean*	Stand Dev.	95% confidence value	Upper	Lower
Part 1: Motivation and readiness for e-health							
1	Health sector trust	4	3.38	0.78	0.21	3.59	3.17
2	Internet trust	4	3.47	1.25	0.34	3.81	3.13
3	Computer concern (anxiety)	4	4.95	1.13	0.31	5.26	4.64
Overall mean			**3.93**				
Part 2: acceptance and adoption							
1	User satisfaction	10	4.98	0.95	0.26	5.24	4.72
2	Usage intention	4	4.52	1.12	0.31	4.83	4.21
3	Navigation	4	5.20	0.92	0.25	5.45	4.95
4	Access	4	5.1	1.05	0.29	5.44	4.86
5	Ease of use	4	5.13	0.75	0.20	5.48	5.08
6	Gained benefits (usefulness)	4	5.26	0.89	0.24	5.50	5.02
7	System architecture	6	4.96	1.09	0.30	5.26	4.66
8	Privacy	5	4.87	0.89	0.26	5.13	4.61
9	Visual values	6	5.28	0.98	0.27	5.55	5.01
10	Security	6	4.78	0.88	0.24	5.02	4.54
Overall mean			**5.03**				
Part 3: Overall quality of information							
1	Comprehensible/ incomprehensible		4.92	1.19	0.32	5.24	4.60
2	Helpful/ unhelpful		5.22	0.89	0.24	5.46	4.98
3	Valuable/ valueless		5.15	0.79	0.21	5.36	4.94
4	Accurate/ inaccurate		4.52	0.99	0.27	4.79	4.25
5	Up-to-date/ out -of-date		4.86	1.09	0.30	5.16	4.56
6	Particular/ general		5.10	0.86	0.24	5.34	4.86

7	Related/ unrelated		5.29	1.14	0.31	5.60	4.98
8	Inclusive/ narrow		5.17	1.20	0.33	5.50	4.84
9	Consistent/ inconsistent		5.33	0.75	0.20	5.53	5.13
10	Widely-scoped/ narrowly-scoped		5.20	1.3	0.35	5.55	4.85
11	Adequate/ insufficient		4.52	1.26	0.34	4.86	4.18
12	Availability/ unavailable		4.51	0.96	0.27	4.78	4.24
13	Reliable/ unreliable		5.11	0.98	0.27	5.38	4.84
Overall mean			**4.99**				
Part 4: Social network blog interaction							
1	Readiness for using social blog in e-health system (driving factors)	6	4.95	0.99	0.28	5.23	4.67
2	Privacy and safety	4	3.55	1.25	0.35	3.90	3.20
3	Usefulness	7	5.21	1.03	0.29	5.50	4.92
4	User engagement	8	5.23	0.98	0.27	5.50	4.96
Overall mean			**4.74**				

Part 1: Motivation and readiness for E-Health
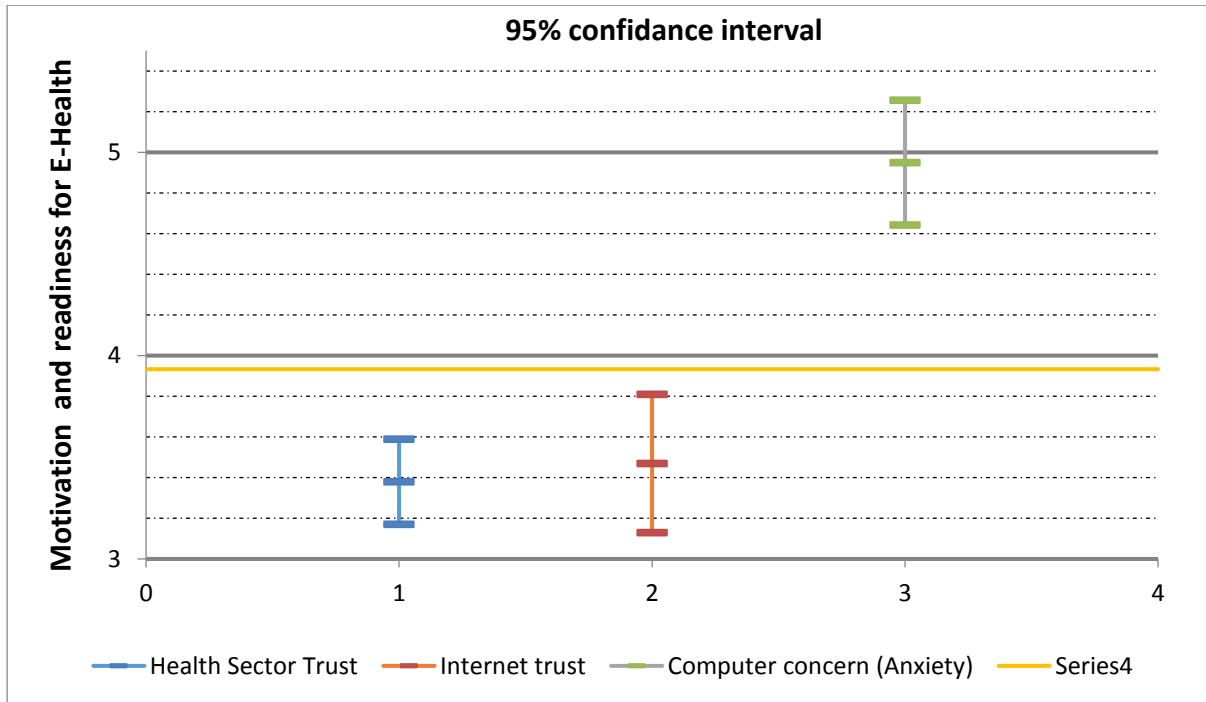
Figure 5.6 Confidence interval and mean for Motivation and readiness for E-health system
Figure 5.6 shows the average scores for motivation and readiness for e-health system using the overall mean for the all items, which is 3.93 and the 95% confidence interval shown for each item of the surveyed part. Two items differed from the total mean at 0.05 significance level (confidence intervals 1 and 2).

As seen from Figure 5.6, the average scores for the trust in e-health and internet are below the overall mean of 3.93. The scores of both of the trust factor indicate insufficient trust in the health sectors in the country and also low trust in using the internet services. The scores of trust in the health sector are lower than the trust level in using the internet for health purposes. The respondents believe that services provided by the MOH donor meet their requirements; therefore a level of low trust is indicated. For internet trust the respondents believe that the IT infrastructure needs more development in order to be more reliable to be used in sensitive services such as health. The mean scores for computer concerns (anxiety) are acceptable compared to the overall mean, indicating that a lot of respondents show a high level of willingness to use the e-health as a new technology, but with concerns regarding trust in MOH and internet infrastructure.

Part 2: Acceptance and Adoption
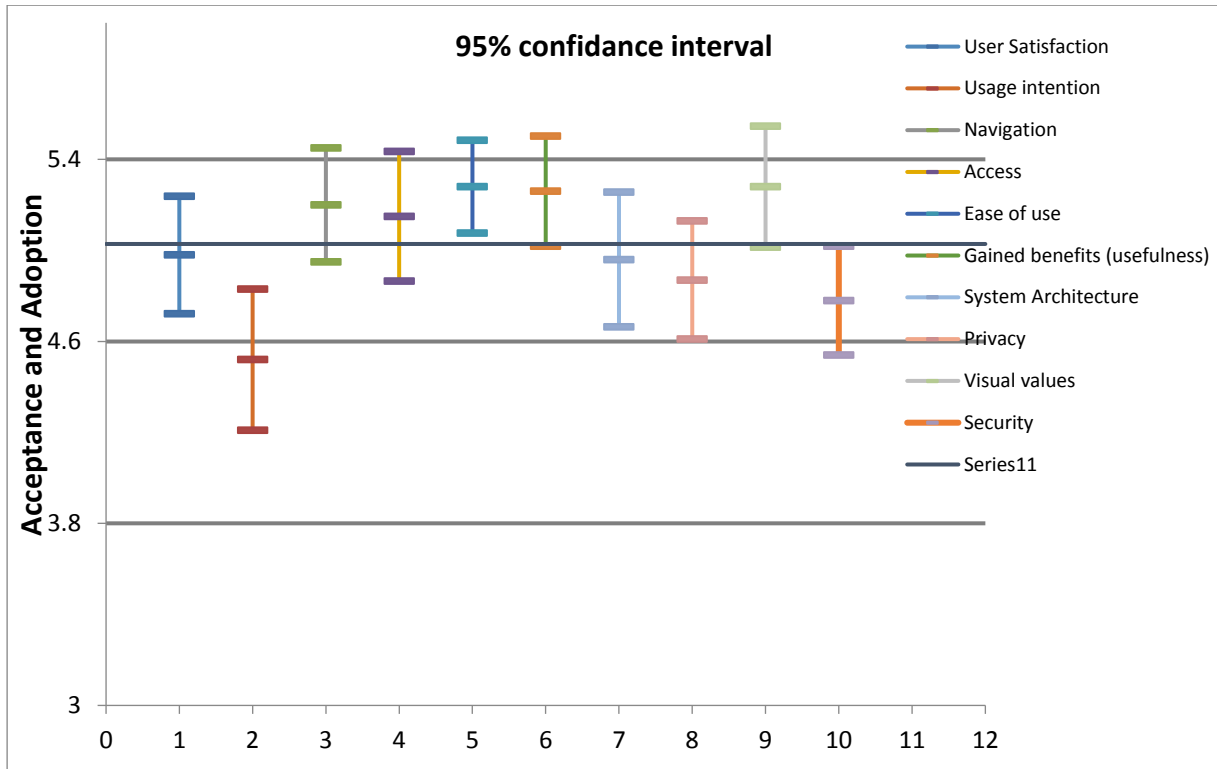
Figure 5.7 Confidence interval for Acceptance and Adoption part

Figure 5.7 shows the average scores of the respondents for acceptance and adoption, with the overall mean for all items of 5.03. Five out of ten items show a mean that is slightly below the overall mean, which are usage intention, system architecture, privacy and security. The other six items were rated over the mean level. The respondents' results reflect the following regarding the low means or scores:

- E-health system needs to gain more trust from the users in order to be adopted and accepted.
- Lower means for the four items are believed to be connected with the previous items in the previous part (trust in e-health and internet).
- The users indicate that they need more security and show concerns regarding their health privacy while using SAIF e-health system.
- The privacy and security concerns are reflected in the intention to use.

- The system architectures and user satisfaction items show a slight difference from the average that is hardly noticed, but on average they are considered acceptable results that do not indicate a serious difference; confidence intervals of 0.05 significance level show an acceptable number of respondents and scores that are above the overall mean value.

- The three lower items' scores need more improvement by the MOH and the designers in order to provide a system that is trustworthy, and more efforts are needed to educate the users about the safety and benefits of using the e-health systems in order to gain their interest in using e-systems.

The 95% confidence interval at 0.05 significance level shown for each item of the surveyed part indicates an acceptable general result for the upper mean value for each item, where most of the upper values for each item recorded a score above the overall mean of the surveyed part, as seen in Figure 5.7. The interval of "intention to use" shows a lower level than the overall mean, which indicates that users have lack of trust in dealing with e-system in health sectors due to security, privacy and governmental trust issues.

The other five items recorded a mean above the overall mean, some of which represent technical and design issues in using the system such as navigation, ease of use, visual values and access, and usefulness represents the amount of gained benefits from using the e-system according to the personal requirements of the e-health user. The surveyed system proved its moderate reliability and efficiency by showing acceptable positive results regarding design, usefulness and technical issues; furthermore, their confidence intervals show an acceptable number of scores that are above the overall mean value, as shown in Figure 5.7.

Nevertheless, the overall mean of the surveyed part shows a value of 5.03 out of 7, which is about 71.85% on the percentage scale, therefore in general the surveyed part showed acceptable positive results that contain some lower scores that are connected with the reasons for the low scores reached in the previous part "motivation and readiness for e-health". The mean scores for the other technical and design issues show scores that are above 71.85% on the percentage scale.

Part 3: Overall quality of information
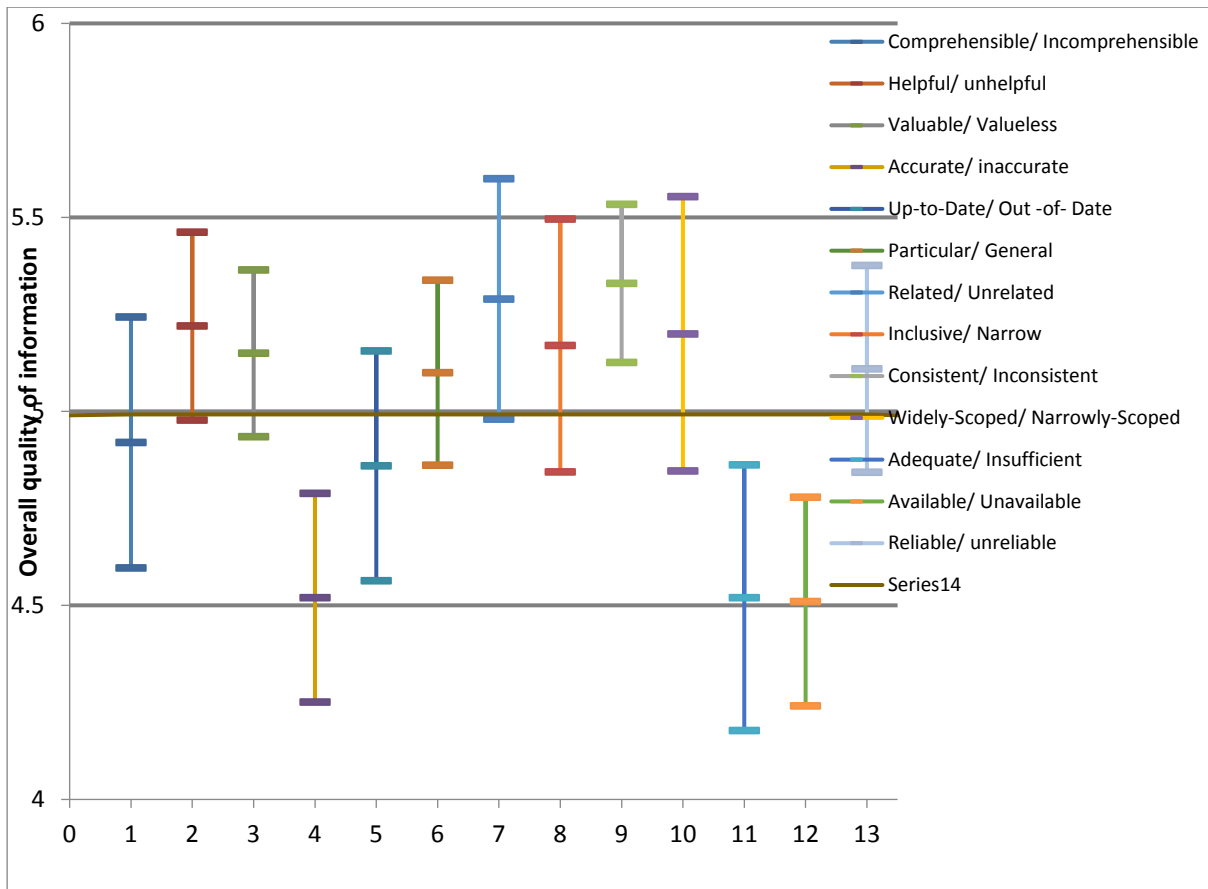
Figure 5.8 Confidence interval for information quality part.

Figure 5.8 shows the average scores of the respondents concerning the overall quality of the information system for SAIF using the overall mean of 4.99 with a 95% confidence interval shown for each item of the surveyed part. Five out of thirteen items show individual mean scores that are below the overall mean of the part, namely Comprehensible/ Incomprehensible, Accurate/ Inaccurate, Up-to-Date/ Out-of-Date, Adequate/ Insufficient and Availability/ Unavailability. The other eight items were rated over the mean level. The respondents' results reflect the following regarding the lower means or scores.

The Comprehensible/ Incomprehensible item indicates a slight difference from the overall mean, thus the e-system needs to include more informative material and wider explanation services in order to render tasks understandable for users, however this could be achieved as

157

a matter of course with training and experience after setting up the system for a trial period to provide users with more experience and extra explanations.

The Accurate/ Inaccurate item indicates a difference from the overall mean that should be investigated more regarding the accuracy of the information provided by the e-health system. More accurate information needs to be provided by doctors and patients concerning treatments and cases respectively, which would replicate to a degree the traditional face-to-face interactions doctors and patients avowedly prefer to use e-health systems. This issue could be treated by more training and by educating the users about the potential easy benefits that they could get by trusting the e-health systems in general.

The Out-of-Date/ Up-to-Date items shows a lower level of scores from the overall mean due to using a trial version for the e-health system in the empirical study, whereby the result indicates the need for a human interference that takes the form of supervision in order to keep updating the users (patients and doctors) with the required information and to provide them with milestones regarding progress in medical cases.

The scores of Adequate/ Insufficient and Availability/Unavailability items show a lower level than the overall mean, which indicates the need of users for extra health services in order to be described as "enough" in the health sector. Patients prefer physical medical tests and require more face-to-face interviews in order to meet their medical concerns, while doctors also generally prefer to use face-to face appointments for the sake of accuracy. However, this issue could be treated by gaining extra trust in dealing with online technology and by educating users about the initial benefits that they could gain before moving to the stage of face-to-face meetings. Furthermore, the e-health system provider should inform the user about the potential benefits that could be gained in arranging medical appointments.

The other eight items show an acceptable level of scores above the overall mean, which indicates positive responses regarding the information quality provided by the e-health system SAIF. Furthermore, their confidence intervals at 0.05 significance level show an acceptable number of scores that are above the overall mean value, as shown in Figure 5.8, whereby some interval are almost above the overall mean in total such as helpful, related and consentient items.

The overall mean of the surveyed part shows a value of 4.99 out of 7, which is about 71.28% on the percentage scale, therefore in general the surveyed information quality has shown acceptable positive results that contain some lower mean scores, as explained and illustrated previously. In general, according to the surveyed percentage of information quality, it is acceptable to say the system is moderately helpful, valuable, particular, related, inclusive, consistent, and widely-scoped, with some reliability in the usability of provided information.

Part 4: Social media blog interaction (blog influence)
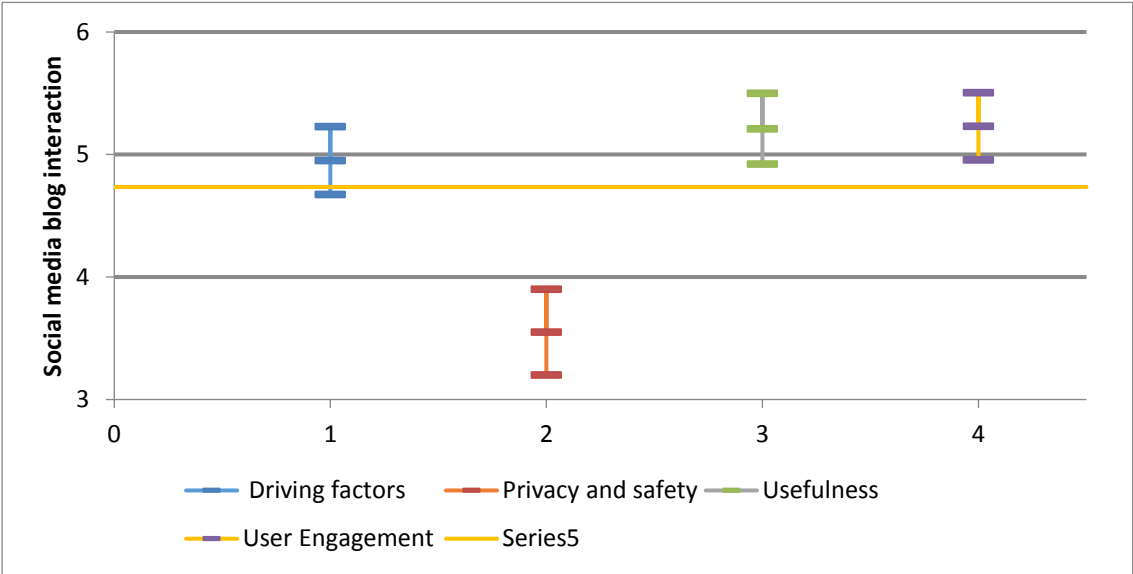
Figure 5.9 Confidence interval for social media blog interaction.

Figure 5.9 shows the average scores of the respondents regarding social media interaction for social blog of e-health system SAIF. The average scores with their 95% confidence interval are compared with the overall mean (4.74) of the results. Three scores out of four have recorded values above the overall mean which are; driving factors, usefulness, and user engagement. The respondents show positive feedback for using SAIF social portal in the followings:

- Delivering their messages and educating themselves about their conditions,
- The doctors and paints indicate an acceptance for the level of engagement that could be achieved between them in case of adopting the e-health system disease management with its social blogger.

- The users indicates a high level of positive feedback regarding the usefulness and user engagements items, where both of the items' means with their lower and upper confidence intervals are totally above the overall mean.

- The users believe generally that they could use SAIF e-health system blog in to create an opportunity to build community that help them in their medical treatment through posting and commenting which attracts more attention by the doctors as a response for the diseases trends in the social media portal,.

- This social portal could be an extra step before using the emergency services which contributes in decreasing eh medical costs.

- Using social blog through e-health systems improves the quality of nursing care through online solutions.

- Furthermore, participants do not mind using social media blog alongside traditional methods of medical participation for patients and doctors.

The driving factor indicates a kind of acceptable level for adopting social network in general to post, comment and communicate with other patients/doctors and to educate patients more about their cases, but this readiness to use and interact with social portals through e-health system shows some concerns through the result of surveyed item "safety and privacy". The safety and privacy items recorded a lower value than overall mean result (3.55); the whole confidence interval with its upper and lower values is recorded below the overall mean, which indicates a major concern regarding safety and privacy by users due to the reasons explored below.

Patients were found to feel worried regarding sharing their medical conditions with strangers even when using an alias, due to their traditional expectation of a high level of confidentiality concerning the disclosure of medical information. The following points were also noted:

- Doctors prefer personal messages to deal with specific patients rather than dealing with general public users, but they do not mind sharing information for the sake of education.

- Patients and doctors believe that face-to-face appointments are preferable to diagnose issues and discuss concerns and treatment.

- Respondents think social network blogs will threaten patient confidentiality.

- The respondents believe that social services provided by e-health system infection disease management do not meet their safety and privacy requirements, indicating a low level of trust.

Patients need more training programs in using the social blog that is integrated with e-health system infection disease management, explaining to them the methods of safe and private usage for the social blog in the e-health system. The mean scores for social network interaction (blog influence) indicate acceptable scores compared to the overall mean, hence a lot of respondents show high level of willingness to use and perceived usefulness of using the social blog for e-health as a new integrated technology with e-health infection disease management, but with marked concerns regarding privacy and safety issues.

Inferential statistics

The statistical difference was tested using inferential statistics for the mean scores of the items with respect to three demographic factors: education level, age, and IT skills or literacy. The three factors were found to be the most important according to the results of inferential statistics tests. The three demographic factors were surveyed in the distributed questionnaire and their influence on three parts of the questionnaire is investigated in this section: motivation and readiness for e-health, acceptance and adoption and information quality.

Table 5.5: The three demographic factors of the significant statistical differences test.

No	Factors and variables	IT skills P value	Education P value	Age P value
	Part 1: Motivation and readiness for e-health			
1	Health sector trust	0.105	0.722	0.059
2	Internet trust	0.058	0.225	0.080
3	Computer concern (anxiety)	**0.002**	0.090	0.067
	Part 2: Acceptance, adoption and information quality			
1	User satisfaction	0.065	**0.000**	0.051
2	Usage intention	0.079	**0.000**	0.076
3	Navigation	0.069	**0.001**	**0.066**
4	Access	0.062	**0.002**	0.078
5	Ease of use	**0.011**	**0.001**	**0.000**
6	Gained benefits (usefulness)	0.059	0.096	0.058
7	System architecture	0.079	**0.002**	**0.002**
8	Privacy	**0.028**	**0.010**	0.069
9	Visual values	0.077	0.056	0.086
10	Security	**0.001**	**0.000**	**0.008**
14	Overall quality of information	0.075	**0.000**	**0.007**

Figure 5.5 shows differences in significance for three demographic factors. The significant differences ($p < 0.05$) are shown in bold for each group. In the first part of the survey (motivation and readiness for e-health) there were no significant differences for the items of health sector trust and internet trust, but there was a significant difference for the item of computer concerns in respect of IT literacy ($p < 0.05$), which indicates the importance of IT skills influence on the readiness for e-health systems, especially computer anxiety. A low level of IT skills tends to cause a high level of concern regarding using computer technology in e-health systems.

The second part of the survey shows several significant differences ($p < 0.05$) in respect of IT skills (three significant differences), education (9 differences) and age (5 differences).

The statistical results in terms of IT skills shows significant differences in respect of ease of use, privacy and security, whereby it indicates the important influence of IT skills and literacy on the issue of using IT services, whereby a low level of IT skills is associated with concerns regarding the privacy, security and ease of use for e-health systems. It is uncomfortable for the users with low level IT skills to trust the privacy and security of e-health systems such as SAIF, which also reflects general difficulties in using e-health systems.

The statistical results in terms of education level shows nine significant differences regarding user satisfaction, usage intention, navigation, access, ease of use, system architecture, privacy, security and information quality, indicating the important influence of education on the issue of using e-health system, as a low level of education was correlated with concerns inhibitive to e-health utilisation regarding the surveyed affected items (especially privacy and security) for e-health systems. It is uncomfortable and moderately complicated for users with low education to use e-health systems such as SAIF.

Furthermore, there are five significant differences ($p < 0.05$) as statistical results for the surveyed items in terms of age differences for the variables: navigation, ease of use, system architecture, security and information quality. It has been shown that older users prefer to address medical issues by face-to-face appointments, which resulted in a major significant difference correlated with age, which is therefore an important factor influencing the acceptance and adoption of the users and the provided information quality; in general the age factor contributes mainly in affecting the general usability of the e-systems.

In summary, inferential statistical tests have been performed for several demographic factors (such as IT skills, age, education, occupation as patients and doctors, frequency of using internet and computer) in order to identify whether there are any significant differences. Those demographic variables were chosen and highlighted in this section because of several significant differences relating to the surveyed items. In conclusion there is an important influence for age, education and IT skills factors on users' motivation and readiness for e-health systems, with marked effects on the variables of acceptance, adoption and information quality.

5.6. Evaluation findings and Conclusions

The outcomes of the evaluation indicate moderate acceptance of the usability of the e-health infection diseases system in KSA, which will result in increasing the level of adoption. The evaluation empirical study has investigated the usability and social network (blog) interaction with e-health systems in terms of motivation of users and readiness for e-health, quality of service and system quality depending on the functionality of SAIF in dealing with infectious diseases management from the perspectives of patients and health professionals. The evaluation exposed in general moderate acceptable positive feedback and results regarding these attributes, with concerns regarding several items such as health sector and internet trust, which affected the level of concern regarding privacy, safety and intention to use for some users, with statistically significant differences have been noticed at $p < 0.05$ for age, educational level and IT skills. The questionnaire was designed depending on several previous studies used to evaluate e-services in different areas, depending mainly on a designed conceptual model for the surviving items.

This evaluation identified four major parts that enhance the trust of users in SAIF: quality of system as a service, quality of provided information, motivation and driving factors for SAIF and social network (blog) interaction and the usability of SAIF. Accordingly, there is chance to improve a number of subjects in the e-health system by enhancing perceived trustworthiness, privacy, and transparency, by more training and education regarding the usage of e-health systems in the health sector for infection and disease management. Such training is believed to be necessary for both patients and doctors. This evaluation indicates that SAIF e-health system as an approach considering design and social issues of the system in accepting, adopting and paving the way for better e-health systems usability with the interaction of integrated social network blogs can improve the experience of the users and enhance their gained benefits, improving service delivery and ultimately quality of care.

Chapter 6: Conclusions

6.1. Overview

It is very important to effectively manage the infectious diseases as they might have adverse effects on an individual or on the society. Moreover, improper or irregular management of infectious disease can lead to various complications which can have both minor and major impact on the population. For example, common cold, an infectious disease can be managed quickly though it can spread effectively. But some other disease causing agents like Ebola virus can very quickly cripple the infected person and kill them.

Implementation of technology has been considered as the major aspect in healthcare services as it not only improves the healthcare processes but also minimises the costs. It is also called as eHealth, which refers to the healthcare practices assisted by the communication systems and electronic processes. The practice of eHealth assisted by mobile devices which are used to capture, analyse and transfer health related information is referred as Mobile Health (mHealth).

In this thesis, we have investigated the usage of a web technology along with social networking module in developing the information system in order to effectively manage the infectious diseases in the region of Kingdom of Saudi Arabia. The achieved main goals in this research project were conducting a feasibility and systematic user perspective study for identifying the needs and the requirements of healthcare personnel and the patients for managing infectious diseases. In conclusion, this thesis achieved the goal of designing and developing a new architecture of next-generation web based infectious disease management system embedding the concept social networking. Also, the thesis focused at performing a preliminary pilot evaluation of the impact of the developed system in collaboration with the kingdom of Saudi Arabia with focus on clinical outcomes and health status. Saudi Arabia is a special case here and they are in a desperate need to such systems, due to the massive season they have every year (i.e., called Haj) and because this case is considered an issue in KSA which needs to be addressed by a solution similar to SAIF.

Moreover, the management of infectious diseases requires in-depth exploration of the latest techniques and technologies, particularly the use of smart and effective web management

tools. This should include the provisioning of emotional support and health education using social networking concepts. Thus, we developed in this PhD thesis an Infectious Diseases Management Framework for Saudi Arabia (SAIF) that uses an effective web-based information system containing social networking and mapping features, and which is tailored according to the healthcare needs of the KSA.

The contributions of this thesis were peer-reviewed and published by a number of high quality conferences. In the following, we summarise the research achievements and discuss the potential future directions.

6.2. Research Achievements

This PhD thesis has addressed issues related to web technology along with social networking module in developing the information system in order to effectively manage the infectious diseases in the region of Kingdom of Saudi Arabia. In the following, the main achievements of the work done in this thesis are elaborated.

In this research project, the objectives set out during the start of the project were achieved. The contributions related to the objectives of the project are summarized below.

- Problem Identification: The first objective to achieve the project aim was to review and identify the current status and potential impact of using Infectious diseases management system in the gulf countries and particularly in the kingdom of Saudi Arabia. To achieve this, we conducted a feasibility and systematic user perspective study for identifying the needs and the requirements of healthcare personnel and the patients for managing infectious diseases in KSA. This study also included a detailed literature systematic review which was conducted to identify the current status and potential impact of using Infectious diseases management system embedding social networking in the gulf countries and particularly in the kingdom of Saudi Arabia. Moreover, an overview of infectious diseases, challenges, and their management was presented in the general and Saudi Arabia context. Previous works and literature related to IDM are reviewed and analysed. The role of information system technologies and mobile applications in IDM is presented. The role of social networking in IDM along with its benefits is also discussed. The information

regarding the IDM in Saudi Arabia is very limited and very few studies are found in this aspect related to the region. The conclusion of the literature study is that there is an immediate need to explore the IDM in Saudi Arabia and also to increase the research studies focusing on the design, development and implementation of web technologies for IDM in the region. Further, it was also noted that there is sufficient infrastructure in KSA in terms of mobile and internet connectivity and there is a good usage of smartphone technologies amongst the population, thus providing a good infrastructural platform for a system like SAIF.

- Design and Development: The main contribution of the research included the design and development of an architecture of next-generation web based infectious disease management system. embedding the concept of social networking. Here, we identified the most relevant behavioural change theories which integrate Infectious diseases management and social networking. The first step in doing that was to define a high level description of infectious diseases management framework for Saudi Arabia (SAIF) by linking the new proposed system with the main challenges identified in the literature review chapters, both in generic terms as well as specific ones oriented towards the citizens of KSA. Next, the SAIF system was designed and developed. The waterfall methodology for the development of SAIF was chosen. Following the requirement specification, the architectural design of SAIF is proposed embedding infections disease management, user management, mapping and tracking infections and social networking modules which are tailored for Saudi users. The modules, their functionality, entities are discussed in many details and illustrated using a number of UML diagrams ranging from use case diagrams to sequence and deployment diagrams.

- Usability study: Another objective of the project is to conduct a usability study of the system that was developed. To achieve this, we conducted a usability study which included performing empirical and perceptual investigations of the e-health system as well as included a validation measurement for SAIF system adoption, acceptance and usability as an approved e-health management system in health sector organisations. Hence, we investigated a preliminary usability study on evaluating the SAIF system in the KSA and in analysing the aspects of user satisfaction and interaction. This evaluation identified four major parts that enhance the trust of users

in SAIF: quality of system as a service, quality of provided information, motivation and driving factors for SAIF and social network (blog) interaction and the usability of SAIF. Accordingly, there is a chance to improve a number of subjects in the e-health system by enhancing perceived trustworthiness, privacy, and transparency, by more training and education regarding the usage of e-health systems in the health sector for infection and disease management. Such training is believed to be necessary for both patients and doctors. This evaluation indicates that SAIF e-health system as an approach considering design and social issues of the system in accepting, adopting and paving the way for better e-health systems usability with the interaction of integrated social network blogs can improve the experience of the users and enhance their gained benefits, improving service delivery and ultimately quality of care.

6.3. Future Work

Infectious disease management system area is considered as an emerging field of modern healthcare in the Gulf region. Significant technical and clinical progress and advanced technologies can be utilized to enhance the performance and ubiquity of such systems. Suggestions for a possible extension to the thesis work are provided below. Hence, the future work which can presently be seen in this field may be classified into a number of categories as follows:

- The fact that the current system does not have a specific infectious disease education programme content. This can be achieved by designing and developing a tailored infectious disease education programme for Saudi patients. Such programs are suitable and fit for mobile infectious disease management system usages. This programme can be developed by using intervention mapping (IM) methodology.

- The intelligent strategies for SAIF system: The major contribution as a future work could be the application and integration of Data Mining techniques for behavioural change issue. This gives the system the ability to suggest to the user of the SAIF behavioural change module extra feedback to his/her infectious disease management status, based on the patterns of previous behaviour. For example, when an infected patient submits his/her behavioural change data to the health care provider server,

the system would automatically suggest to him/her the best way for improving and managing infectious disease conditions.

- The design of SAIF system: As the SAIF system was mainly designed for infected patients. Design and development a tailored mobile systems for infected patients can be considered in future work by designing and adding a gamification concept for such patients and functionalities for different ages of patients.

- The clinical study: a power calculation recommended 19 participants to produce paired t-test results (one-tailed) with 95% power (based on a large effect size, $d = .8$; and recommended 35 participants per group to produce independent samples t-test results (one-tailed) with 95% power, based on a large effect size, to compare change between control and intervention groups in future SAIF trials). This larger sample would be feasible in a national study to replicate this study in central, east, west, north and south Saudi Arabia. To improve external validity, a more sophisticated random sampling strategy is also recommended in future trials, such as multi-stage cluster random sampling within each region, recruiting infected patients from primary health centres as the sampling frame. This study should then be replicated in national studies of Bahrain, UAE, Iraq, and Egypt. Validation is then recommended for SAIF to use in English-speaking countries, to further validate and widen the marketability of SAIF to help patients self-manage their diseases, and share knowledge and support with their peers. Importantly, SAIF is currently available exclusively on Samsung' android operating system. Therefore, Samsung should be approached to fund part of the costs of a future national feasibility study, including supply of Galaxy smartphone and associated charges for participants. The SAIF system is currently being configured for use on IOS (iPhone), which should significantly broaden its usage and appeal to the larger market of diabetes patients across the world, and this will also require usability studies.

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Appendix A

E-Health management system

Part A: Personal Background

* Q1: What is your age?

○ 18 to 24
○ 25 to 34
○ 35 to 44
○ 45 to 55
○ 55 +

* Q2: What is your gender?

○ Female
○ Male

* Q3: Which of the following best describes your current occupation as a user?

○ Senior Doctor
○ Junior Doctor
○ Recptionest
○ Patient
○ Other (please specify)

* Q4: What is the highest level of school you have completed or the highest degree you have received?

○ Less than high school degree
○ High school degree or equivalent (e.g., GED)
○ Some college but no degree
○ Associate degree
○ Bachelor degree
○ Graduate degree

1

* Q5: Do you use internet regularly at home?

○ Yes

○ NO

* Q6: Do you use internet regularly at work/school/ university?

○ Yes

○ NO

* Q7: In a typical day, how many hours you use a computer at home/work/school?

○ less than 1 hour

○ 1-3 hours

○ 4-6 hours

○ +6 hours

* Q8: How do you describe your skills in information technologies (IT)?

○ Very low

○ Low

○ Medium

○ High

○ Very high

○ don't know what IT is

2

Part B: Motivation for E-Health

* To what extend do you agree with the following sentences? please choose the appropriate number on the 7-point scale.

Health Sector Trust

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
I think I can trust health sector agencies and facilities.	◯	◯	◯	◯	◯	◯	◯	◯
Health sector agencies can be trusted to do online transaction faithfully.	◯	◯	◯	◯	◯	◯	◯	◯
I trust health sector agencies and facilities to keep my best interest and health in mind.	◯	◯	◯	◯	◯	◯	◯	◯
In my opinion health sector are trustworthy.	◯	◯	◯	◯	◯	◯	◯	◯

* Internet trust

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
The internet has enough protection to make me feel protected using it to transact personal business with Health sector agencies.	◯	◯	◯	◯	◯	◯	◯	◯
I feel assured that legal and technological structures is enough as protection from legal problems.	◯	◯	◯	◯	◯	◯	◯	◯
Internet in general is a safe and strong environment to deal with my health information.	◯	◯	◯	◯	◯	◯	◯	◯
Overall I have trust using online payments over internet.	◯	◯	◯	◯	◯	◯	◯	◯

3

185

*Computer concern (anxiety)

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
I do not have any concern using computers.	○	○	○	○	○	○	○	○
Working with computers makes me anxious.	○	○	○	○	○	○	○	○
I feel that using computers is safe in general.	○	○	○	○	○	○	○	○
Using computer makes me uncomfortable.	○	○	○	○	○	○	○	○

4

E-Health management system

Pacrt C: SAIF Using and Tasks Scenarios.

Please use the provided E-helath system SAIF and carry out the following tasks by using a reliable web browser such as (internet Explorer, Mozilla and Google chrome)

1. Please take 5 minutes to navigate the provided tools and tabs in the web application.

2. Only applicable for Health sector staff: You are a doctor/ and want to communicate with your patient by diagnosing the disease according to the provided medical health history which are given by the patient.
- Please use the tools in the system to summarise the patient case and prescribe the suitable management (investigation and treatment).
- Communicate with the messages from patients
- Create invoices according to the provided treatment.
- Change your profile data and settings
- Create and arrange appointments with the patients.
- Interact with patients through the social network posts
-

3.Only applicable for Health sector staff: You are a nurse/ recipients
- Organising the dashboard tasks
- Arrange appointment between a doctor and a patient, and report the doctor about any further requests from patients.
- Create invoices according to the provided treatment.
- Change your profile data and settings
- Create and arrange appointments with the patients.
- Interact with patients through the social network posts

4.Only applicable for Patients:
- Request an appointment with a specific doctor according to his profile (date, priority and symptoms)
- Get medical background about your diseases (description, guidelines, symptoms, recommendations and treatments)
- Change your profile data and settings
- Contact with your doctor for any new symptoms.
- Interact with other patients and doctors through the social network posts

Please feel free to ask any questions regarding SAIF system tabs and usage. Any enquiry is welcome. Also using any extra features in the system by you is preferable.

5

E-Health management system

1. Acceptance and Addoption

To what extend do you agree with the following sentences? please choose the appropriate number on the 7-point scale.

User Satisfaction

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
I think that I would like to use SAIF E-health system frequently.	◯	◯	◯	◯	◯	◯	◯	◯
I found the system unnecessarily complex.	◯	◯	◯	◯	◯	◯	◯	◯
I believe the system is easy to use.	◯	◯	◯	◯	◯	◯	◯	◯
I think a help is needed by a technical supporter in order to use the system.	◯	◯	◯	◯	◯	◯	◯	◯
The functions and tools in this system are well integrated.	◯	◯	◯	◯	◯	◯	◯	◯
I thought there was too much contradiction in this system.	◯	◯	◯	◯	◯	◯	◯	◯
I believe that most users would learn to use this system very quickly.	◯	◯	◯	◯	◯	◯	◯	◯
I found the system was very uncomfortable to use.	◯	◯	◯	◯	◯	◯	◯	◯
I felt very confident using the system.	◯	◯	◯	◯	◯	◯	◯	◯
I think that I need more knowledge an skill to learn in order to use the system.	◯	◯	◯	◯	◯	◯	◯	◯

6

Intention to use

	1 Strongly disagree	2	3	4	5	6	7 Strongly agree	Don't know
I will frequently use SAIF E-health in the future.	◯	◯	◯	◯	◯	◯	◯	◯
I will use SAIF –Health system rather than other sources for medical services.	◯	◯	◯	◯	◯	◯	◯	◯
I will recommend others to use this system.	◯	◯	◯	◯	◯	◯	◯	◯
I intend to use the system if I have access to it.	◯	◯	◯	◯	◯	◯	◯	◯

7

E-Health management system

2. System Quality

Navigation

	1- Strongly dissagree	2	3	4	5	6	7- Strongly agree	Don't know
SAIF has a sufficient and suitable number of links.	◯	◯	◯	◯	◯	◯	◯	◯
SAIF links are descried and clear to use.	◯	◯	◯	◯	◯	◯	◯	◯
In SAIF it is easy to navigate back and forward between pages.	◯	◯	◯	◯	◯	◯	◯	◯
In SAIF, information appeared quickly by clicking tabs.	◯	◯	◯	◯	◯	◯	◯	◯

Access

	1- Strongly dissagree	2	3	4	5	6	7- Strongly agree	Don't know
SAIF is receptive to my request.	◯	◯	◯	◯	◯	◯	◯	◯
Text and graphics are loading quickly in SAIF.	◯	◯	◯	◯	◯	◯	◯	◯
The pages in SAIF are loaded easily and quickly.	◯	◯	◯	◯	◯	◯	◯	◯
The homepage of the system is loaded quickly.	◯	◯	◯	◯	◯	◯	◯	◯

Ease of use

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
Learning SAIF system is easy for me.	○	○	○	○	○	○	○	○
It will be impossible to use JSAIF without a supporter help.	○	○	○	○	○	○	○	○
My usage for SAIF is described as understandable and clear.	○	○	○	○	○	○	○	○
Using SAIF system requires a lot of thinking and mental effort.	○	○	○	○	○	○	○	○

Gained benefits

	1- Strongly dissagree	2	3	4	5	6	7- Strongly agree	Don't know
Using SAIF enables me to finish my task quicker than before.	○	○	○	○	○	○	○	○
Using SAIF improves my task performance.	○	○	○	○	○	○	○	○
Using SAIF increase my task productivity.	○	○	○	○	○	○	○	○
Using SAIF improves my task quality.	○	○	○	○	○	○	○	○

9

System Architecture

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
SAIF content is well organized.	○	○	○	○	○	○	○	○
The tabs section is well structured with the information, tools and services.	○	○	○	○	○	○	○	○
The organisation of the page makes the content easy to read.	○	○	○	○	○	○	○	○
SAIF tabs and sub-tabs are well organised according to a logical categories.	○	○	○	○	○	○	○	○
The most important information is easy to retch and notice	○	○	○	○	○	○	○	○
Related information is existed in categories.	○	○	○	○	○	○	○	○

Privacy

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
I am worried about the potential abuse of my personal data in SAIF.	○	○	○	○	○	○	○	○
t's not comfortable to trust SAIF with my personal health data/ my patient's data.	○	○	○	○	○	○	○	○
It is important to state the limit of personal data that are allowed to be taken by SAIF.	○	○	○	○	○	○	○	○
t is important to focus more on privacy issue in SAIF.	○	○	○	○	○	○	○	○
I have concerns about the persons will have access to my personal data/ patient's data in SAIF.	○	○	○	○	○	○	○	○

Visual values

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
The layout of SAIF is simple compared to its several contents.	◯	◯	◯	◯	◯	◯	◯	◯
The design of SAIF is clear and understandable.	◯	◯	◯	◯	◯	◯	◯	◯
Tabs layout makes tasks easier.	◯	◯	◯	◯	◯	◯	◯	◯
Graphical visual presentation aids are practical.	◯	◯	◯	◯	◯	◯	◯	◯
SAIF visual presentation aids are useful.	◯	◯	◯	◯	◯	◯	◯	◯
SAIF interface has suitable colours and font size.	◯	◯	◯	◯	◯	◯	◯	◯
SAIF is visually attractive.	◯	◯	◯	◯	◯	◯	◯	◯

Security

	1- Strongly disagree	2	3	4	5	6	7- Strongly Agree	Don't know
I have concerns regarding fraud when using the system over SAIF.	◯	◯	◯	◯	◯	◯	◯	◯
I have concerns regarding the user authentication and authorization by using SAIF.	◯	◯	◯	◯	◯	◯	◯	◯
In general I have concerns regarding using SAIF.	◯	◯	◯	◯	◯	◯	◯	◯
I have concerns about the susceptibility of SAIF to online hackers.	◯	◯	◯	◯	◯	◯	◯	◯
I feel worried about the access of some persons to my medical personal data/patients data.	◯	◯	◯	◯	◯	◯	◯	◯
It is very important to have secure login account for SAIF.	◯	◯	◯	◯	◯	◯	◯	◯

11

E-Health management system

3. Overall quality of Information

The below part contains 13 rows where each raw contains tow contradicted words that describe the overall system quality depending of the scale from 1 t0 7. Each pairs shows an extreme contrast. This gradation in scale enables you to describe your general experience regarding the quality of the provided service. There are no right/wrong answers in this section as it supposed to reflect your own experience and opinion.

QS1

1- Comprehensible	2	3	4	5	6	7- Incomprehensible

QS2

1- Helpful	2	3	4	5	6	7 - Unhelpful

QS3

1- Valuable	2	3	4	5	6	7- Valueless

QS4

1- Accurate	2	3	4	5	6	7- Inaccurate

QS5

1- Up-to-Date	2	3	4	5	6	7- Out -of- Date

QS6

1- Particular	2	3	4	5	6	7- General

12

QS7

1- Related	2	3	4	5	6	7- Unrelated

QS8

1- Inclusive	2	3	4	5	6	7- Narrow

QS9

1- Consistent	2	3	4	5	6	7- Inconsistent

QS10

1- Widely-Scoped	2	3	4	5	6	7- Narrowly-Scoped

QS11

1- Adequate	2	3	4	5	6	7- Insufficient

QS12

1- Available	2	3	4	5	6	7- Unavailable

QS13

1- Reliable	2	3	4	5	6	7- Unreliable

13

195

E-Health management system

Part D: Social network

To what extend do you agree with the following sentences? please choose the appropriate number on the 7-point scale.

Readiness for using social blogger in e-health system (driving factors)

	1- Strongly disagree	2	3	4	5	6	7- Strongly agree	Don't know
I welcome the introduction of Social media in e-health.	○	○	○	○	○	○	○	○
I welcome the introduction of social media blog in nursing practice.	○	○	○	○	○	○	○	○
Social media blog creates an opportunity to reinforce messages.	○	○	○	○	○	○	○	○
Social media blog creates an opportunity to build community.	○	○	○	○	○	○	○	○
Social media creates an opportunity to educate individuals.	○	○	○	○	○	○	○	○
Social media can be used alongside traditional methods of participation.	○	○	○	○	○	○	○	○

Privacy and safety

	1- Strongly disagree	2	3	4	5	6	7- Stronlgy agree	Don't know
I think social media blog will improve patient safety.	○	○	○	○	○	○	○	○
I think social media blog will secure as paper-based records.	○	○	○	○	○	○	○	○
I think social media blog will not threaten patient confidentiality.	○	○	○	○	○	○	○	○
Social media gives more encouragement to post about my case.	○	○	○	○	○	○	○	○

14

Usefulness

	1- Stronlgy disagree	2	3	4	5	6	7- Strongly agree	Don't know
I think social media blog will save time.	○	○	○	○	○	○	○	○
I think social media blog will strength the patient's relationship with nursing staff.	○	○	○	○	○	○	○	○
I think social media blog will improve patient care.	○	○	○	○	○	○	○	○
I think social media blog will not change nursing practice.	○	○	○	○	○	○	○	○
I think social media blog will improve the quality of nursing care.	○	○	○	○	○	○	○	○
Social media blog will help prevent/ reduce emergency hospital admissions.	○	○	○	○	○	○	○	○
I can receive other helpful news and interests.	○	○	○	○	○	○	○	○
Don't know	○	○	○	○	○	○	○	○

15

197

User Engagement

	1- Strongly disagree	2	3	4	5	6	7- Strongly Agree	Don't know
I can participate in a health related chat blog.	○	○	○	○	○	○	○	○
I can provide comments easily.	○	○	○	○	○	○	○	○
Social media blog will allow me to intervene before a patient's condition exacerbates.	○	○	○	○	○	○	○	○
I obtain easier communication channels to patients.	○	○	○	○	○	○	○	○
I communicate easily with various doctors/patients within the department.	○	○	○	○	○	○	○	○
I can search for information on health research.	○	○	○	○	○	○	○	○
I can create a social network with patient/patients.	○	○	○	○	○	○	○	○
I can coordinate with staff within the organization.	○	○	○	○	○	○	○	○

16

Appendix B

1-Please mark the age group that you belong:

18-40 Years

41-50 Years

50-66 Years

66-Over

2- Your gender is:

Male

Female

3- From where do you have to access to the internet?

Pc/laptop

Mobile

Other

4- Do you have a cell phone for personal use?

Yes

No

5- How often do you use web?

Often

Less often

Rarely

Never

6- How often do you use your email, social networking, news, online shopping and health information? (18-40)

Email

Social networking

News

Online shopping

Health information

7- How often do you use your email, social networking, news, online shopping and health information? (41-50)

Email

Social networking

News

Online shopping

Health information

8- How often do you use your email, social networking, news, online shopping and health information? (51-65)

Email

Social networking

News

Online shopping

Health information

9- How often do you use your email, social networking, news, online shopping and health information? (over66)

Email

Social networking

News

Online shopping

Health information

10- Are you engaged in at last one online social network?

Yes

No

11- On average how much time do you spend on the most preferred social network per week?

Less than an hour

1-2 hours

3-4 hours

5-6 hours

More than 6 hours

12- What do you use social networks for? - Find new friends?

Yes, very often

Yes, but rarely

No

13- What do you use social networks for? - Update your profile?

Yes, very often

Yes, but rarely

No

14- What do you use social networks for? - Spread awareness about health?

Yes

No

15- Would you like to have a unique web-based portal and system for managing infectious diseases?

Yes

No

16- Would you like to receive education using a web-based system for providing help in infectious diseases management and avoidance?

Yes

No

17- Would you prefer to use social networking as an intervening module for IDM?

Yes

No

18- Would you like to view the spread of infection using maps?

Yes

No

19- Would you like to receive real-time feedback by e-mail or SMS?

Yes

No

20- What services would you like to be included in the Saudi infectious diseases social networking?

Sharing videos

Book appointment

Alert

Trend chart

Immunization board

Messages

Appendix C

A. Standard errors managed by the SAIF portal

i.   User is not authenticated

The HTTP code related to the "user is not authenticated" error is "403". The structure of this error is given as follows.

```
{

   "detail": "Authentication credentials were not provided."

}
```

ii.   Validation fail

The HTTP code related to the "validation fail" error is "400". The response structure of this error contains a set of invalid fields. Under each field, there are list of error messages stored. Also there is a special key called "detail". This key is used to describe errors which are referred to the entire request rather than a concrete field.

```
{
   "failed_field_1": [
      "Error description 1",
      "Error description 2"
   ],
   "failed_field_2": [
      "Error description 1",
      "Error description 2"
   ],
   "detail": [
      "Non-field error 1",
      "Non-field error 2"
   ]
}
```

iii. Permission denied

The HTTP code related to the "permission denied" error is "403".

The Response body is similar to the earlier authorization fail error, although the error message can vary depending on the type of action which the user wanted to perform.

```
{
    "detail": "Action-specific error message"
}
```

B. Authentication API

i. Request structure:

The request structure is enquired as follows: POST /api/myself/login/

```
{

    "username": "example_user",

    "password": "qwerty"

}
```

ii. Success response:

The HTTP code related to the success response is 200, and the response body is structured as follows:

```
{

    "token": "authorization token value",

    "user": {

        // User representation described above

    }
```

```
}
```

iii.   Fail response:

The HTTP code related to the fail response is 403, and the response body is structured as follows:

```json
{

    "detail": "Incorrect authentication credentials."

}
```

C. Structure of disease representation

```json
{

  // disease ID

  "uuid": "f87ace10-67ab-46fe-b828-b96961e31c7d",


  // basic information

  "scientific_name": "name used by specialists",

  "name": "name used by non-specialists",

  "description": "Description: potentially long text",


  // if you are writing:

  "category": "category UUID",

  // if you are reading:

  "category": {
```

```
    "uuid": "category uuid",

    "name": "category name"

},



// number of comments and its average rate

"num_comments": 5,

"avg_rate": 3.8,



// it is associations between Disease and Identifications

"identifications": [

   {

      // ID of **Association**, not Identification

      "uuid": "7ccad67b-ecd1-47a2-ad2f-30cb1b3339f9",



      // Identification itself. In detail view it is Identification ID, in full
view - Identification body in brief form.

      "identification": ...,

   }

   // others...

],
```

```
    // In detail view it is arrays of IDs. In full view it is arrays of related
objects bodies.

    "recommendations": [...],

    "treatments": [...],

    "guidelines": [...]
```

D. Implementation of disease management entities

a. Categories

```
{

    // Category ID used to allow changing the category name without

    // breaking relations between categories, diseases and infections.

    // Read-only field.

    "uuid": "e834d6dc-2f7c-48c1-84b7-e07f2c861d16",



    // Disease category names are unique and identification category names
are unique,

    // existence of disease category and identification category with same
names is allowed

    "name": "arbitrary string"

}
```

b. Guidelines

```
{

    "uuid": "ID of Guideline",

    "disease": "ID of Disease to that this Guideline is related",

    "title": "short string",

    "description": "long text"

}
```

c. Treatments

```
{

    "uuid": "ID of Treatment",

    "disease": "ID of Disease to that this Treatment is related",

    "description": "long text",

    // date and time of creation and last update

    "created": "2016-04-12T16:04:25.527853Z",

    "updated": "2016-04-12T16:04:25.527921Z"

}
```

d. Recommendations

```
{

    "uuid": "ID of Recommendation",

    "disease": "ID of Disease to that this Recommendation is related",
```

```
    "title": "short string",

    "description": "Long text",

    "steps": [

        "Text of step #1",

        "Text of step #2",

        "Text of step #3"

    ],

    // date and time of creation and last update

    "created": "2016-04-12T16:04:23.594212Z",

    "updated": "2016-04-12T16:04:23.594276Z"

}
```

e. Comments

```
{

    "uuid": "ID of comment",

    "author": {

        "username": "m.murphy",

        "email": "m.murphy@mail.com",

        "first_name": "Max",

        "last_name": "Murphy",
```

```
        "role": "doctor",

        "photo_url": "/url/to/photo.png",

        "gender": "M",

      },

      "rate": <integer from 0 to 5>,

      "comment": "Comment text",

      "created": "2016-04-19T07:58:31.443288Z", // creation date and time


      // present if current user is author if the comment and if it was created
    within last hour

      // otherwise this field is omitted, even if current user is admin and in
    fact comment can be changed by the user.

      "changeable": true

    }
```

E. Categories API function codes

a.   Listing and search

GET /api/diseases/categories/
GET /api/identifications/categories/
We notice here the output format is: list of instances. And the Query parameter is: q which does filtering by name, and it is case insensitive.

b.   Single category view

GET /api/diseases/categories//
GET /api/identifications/categories//
The output format is: single instance.

c.   Create/update the category

POST /api/diseases/categories/
POST /api/identifications/categories/
PUT|PATCH /api/diseases/categories//
PUT|PATCH /api/identifications/categories//
The output format is: single instance. And the Accepted fields are: only name (since uuid is read-only). If category with this name already exists then you'll get this error "Category with this name already exists" on name field.

d.   Delete the category

DELETE /api/diseases/categories//
DELETE /api/identifications/categories//

F. Comments API

a. List comments for disease
        GET /api/disease/<disease_uuid>/comments/

The output format is: list of comments. And this is available for: anyone. The order is based on date and time creation.

b. Create comment

POST/api/disease/<disease_uuid>/comments/

This is available for only doctors. The accepted field are: *rate*, *comment*. And this will return: representation of created comment.

c. Edit comment
        PUT|PATCH   /api/disease/<disease_uuid>/comments/<uuid>/

This is available for admins and author of comment (if comment was created in last hour). The accepted fields are: *rate*, *comment*. And this will return: representation of the comment.

d. Delete comment

DELETE   /api/disease/<disease_uuid>/comments/<uuid>/

This available for admins and author of comment (if comment was created in last hour).

G. Appointments and Consultation Reports Representation

a. Appointment representation

```
{
    // appointment identifier, read-only
    "uuid": "1a153e91-4276-4d6d-9821-58fff194b0cc",

    // patient who was appointed
    "patient": {
        "username": "o.jones",
        "email": "o.jones@mail.com",
        "first_name": "Oliver",
        "last_name": "Jones",
        "date_joined": "2013-09-17T22:22:58Z",
        "birth_date": "1971-06-17",
        "gender": "M",
        "role": "patient",
    },

    // appointment date and time
    "appointed_datetime": "2016-04-28T11:00:00Z",
```

```
    "priority": "normal",  // choices are "normal" and "high"

  "description": "Arbitrary text",


  // doctor who is assigned to this appointment. read-only, null if
nobody is assigned
  "assignee": {
    "username": "m.murphy",
    "email": "m.murphy@mail.com",
    "first_name": "Max",
    "last_name": "Murphy",
    "role": "doctor",
  },
  "doctor": "username of doctor to assign", // write-only, alias for
assignee

  // date and time of last Patient's confirmation
  "confirmed_by_patient": "2016-04-26T08:20:23.128053Z",


  "arrived_datetime": "2016-04-28T10:55:00Z",
  "waiting_time": 315,  // how long patient is waiting, in seconds


  // date and time of appointment creation and last update
  "created": "2016-04-26T07:40:23.128053Z",
  "updated": "2016-04-26T07:40:23.128091Z",


  // denotes whether appointment was confirmed by assigned doctor;
read-only
  "confirmed_by_doctor": false,


  "attachments": [
    // list of all files attached to this appointment
```

```
      // see Attachment Representation for details
    ],
```

```
    "has_report": false, // boolean denoting whether this appointment
has report
    "has_disease": false, // whether this appointment has associated
disease. always false if there is no report
    "report": null or Consultation Report representation
}
```

Field *report* appears in detail representation and in list representation with query parameter *full=true*. All other fields appear in both list and detail representation.

b. Consultation report representation

```
{
    "medical_history": "text",
    "examination": "text",
    "diagnosis": "text",
    "treatment": "text",
    "diagnosis_report": "text",
    "other_disease": "text",

    // you can only update whole list, there are no way to append to it or
remove specific element
    "prescription": [
      {
        "description": "text",
        // when you are reading: medication is object
        "medication": {
          "uuid": "identifier",
          "name": "human readable name"
```

```
        },
        // when you are writing: medication should be identifier
        "medication": "31d4f48e-0e47-4b89-9e09-8d45c84b70f3"
    },
    ...
],


// when you are reading: disease object
"disease": {
    // see disease representation docs
    // here will be the list-view representation
},
// when you are writing: uuid of disease
"disease": "75079485-70fb-d46a-0bb4-91ec4fc2c7ad",


"corrections": {
    "medical_history": [
        {<correction representation without field "target">}
    ],
    "examination": [...],
    "diagnosis": [...],
    "treatment": [...],
    "diagnosis_report": [...],
    "other_disease": [...]
},
"editors": {
    <username>: {
        "username": <username>,
        "email": "editors email",
        "photo_url": null,
        "first_name": "editors first name",
```

```
        "last_name": "editors last name",

        "role": "doctor"   // always doctor because only doctors can
  create corrections

      }

    },


    // write-only parameter. can be omitted and defaults to false
    // if set to true closes the appointment and moves it to the archive.
    "close": false;

  }
```

c. Correction representation

```
{
    // ID of correction
    "uuid": "7f26d0d5-6e98-4c4f-9aa2-3e1f7d2d2726",


    // username of author. authors always are doctors
    "author": "m.graham",


    // what field of report is corrected
    // choices: "medical_history", "examination", "diagnosis",
    // "treatment", "diagnosis_report", "other_disease"
    "target": "examination",


    // correction content
    "data": "edition #1",


    // date and time when correction was created. ISO 8601
    "created": "2016-05-20T10:01:13.766331Z"
}
```

The fields are Writable: *target*, *data*.

d. Medication representation

```
{
    "uuid": "identifier",
    "name": "human readable name"
}
```

e. Attachment representation

```
{
    "uuid": "attachment identifier",
    "name": "name of the file; unique per appointment",
    "description": "arbitrary string",
    "file_url": "URL for downloading the file",
    "content_type": "MIME type of the file. Can be used for rendering
corresponding file icon"
}
```

H. Appointments reading API

a. Listing

GET /api/appointments/

The output format is: *list of objects. This is a*vailable for *doctors*, *nurses*, *receptionists* and *patients*. The patients can see only appointments associated with themselves such as: appointments of other patients should not be included into the list.

Confirmed: this shows whether or not appointment confirmed by doctor.
-- If omitted or passed empty string: no filtering
-- If passed true or false: filter only assigned with specified confirmation status

Patient: this requires username of patient.
-- If passed, returns only appointments with specified patient.

Category: this is a valid choice: *active*, *inprogress*, *archive*. Default: *active*.
-- *active* (or parameter not used) - returns all non-closed appointments
-- *new* - returns only non-closed appointments **without** consultation report created.
-- *inprogress* - returns only non-closed appointments **with** consultation report created.
-- *archive* - returns only closed appointments; parameters *confirmed* and *assignee* are ignored

from_date, **before_date***: this is used to perform filtering by appointment date
--   input   format   is   YYYY-MM-DD
-- *from_date* works inclusive, i.e. appointments on specified date will be included into response
-- *before_date* works exclusive, i.e. appointments on specified date will NOT be included into response

full: this allows to include full consultation report into response.
--   True   values: *1*, *t*, *T*, *true*
--   False   values: *0*, *f*, *F*, *false*
-- Defaults to false.

    b. Detail view
           GET /api/appointments/<uuid>/

The output format is: *single object. There are n*o query parameters. This is available for *doctors*, *nurses*, *receptionists* and *patients*. The patients can see only appointments associated with themselves: if patient requests appointment of other patient, then the patient gets a 404 not found error page.

I. Appointment update API

           PUT|PATCH/api/appointments/<uuid>/

This is available for receptionists only. Then the Acceptable fields are: appointed_date, description, doctor, priority. If an appointment was confirmed by a doctor, it will be unconfirmed again.

J. Appointments cancelling API

DELETE /api/appointments/<uuid>/

This is available for **receptionists** only. This API marks the appointment as cancelled so it will become inaccessible with any API. However the information will be available on the system as deleted.

K. Appointment confirmation API

POST /api/appointments/<uuid>/confirm.

This is available for **patients** and **doctor**.

When this is sent by doctor, then the following occurs:
-- Appointment becomes *assigned to the doctor* and *confirmed by the doctor;*
-- If an appointment is already assigned to another doctor, then a request fails;
-- This action is kind of an appointment update, so the *updated* field changes to the current moment;
-- If an appointment is already assigned to a current doctor and confirmed, then nothing is changed (*updated* field also untouched)

When this is sent by a patient, then the following occurs:
-- Field *confirmed_by_patient* changes to the current moment;
-- This action is not a kind of an appointment update, so the *updated* field is untouched.

DELETE /api/appointments/<uuid>/confirm. This is available only to **doctors**.

-- Appointment becomes *unassigned to any doctor* and *confirmed_by_doctor* becomes false (if was not);
-- If appointment is assigned to another doctor (not sender of request), then request will fail;
-- If appointment is unassigned, then request will fail;
-- Purpose of this API is only to allow doctors to say "I don't want to take this appointment";

-- This action is a kind of appointment update, so the *updated* field changes to the current moment.

L. SAIF Social Network (Blogs and Messenger)

Blogging API

    a.   Articles listing

           GET /api/articles/.

This API returns list of articles. In addition, this API is available for everyone, even for unauthenticated users. A list of query parameters are:

Order: It does ordering of the results. It is to validate choices: *most-recent* (default), *most-commented*, *most-viewed*.

tags: comma-separated list of tags. Best matches (i.e., has all tags) are first, then returns worse matches (does not have all tags).

Author: this parameter accepts a username of an author to do filtering. If omitted, then there is no filtering performed.

Title: the words are separated by "+". The articles are matched if any of the words are present in the article's title.

    b.   Articles detail view

           GET /api/articles/<article uuid>/.

This API returns a specified article. It is also available for everyone, even for unauthenticated users.

c. Comments listing

GET /api/articles/<article uuid>/comments/.

This API returns list of comments for specified article. It is also available for everyone, even for unauthenticated users. Comments are ordered from the earliest to the most recent.

d. Articles creation

POST /api/articles/.

The fields are Writable: *title*, *foreword*, *content*, *tags*. Also, this is available for the following roles: *Admin*, *Doctor*, *Nurse*, *Policy Maker.*

e. Articles update

PUT|PATCH /api/articles/<uuid>/.

The Writable fields are: *title*, *foreword*, *content*, *tags*. This API is available for the author of the article, for the *super-admins* and for the *admins* in the same hospital as the author.

f. Article cover image

i. Upload

PUT /api/articles/<uuid>/cover_image.

This API accepts multipart-encoded data with the field *image* which contains the file. The access policy is as same as the article updating. Then the API returns objects with single field *cover_image_url* that contains URL to uploaded image.

ii. Deletion

DELETE /api/articles/<uuid>/cover_image. The access policy is as same as the article updating. This does not accept any parameters and does not return any data. This object only deletes the image.

g. Articles deletion

DELETE /api/articles/<uuid>/. This API is available for the author of the article, for *super-admins* and for *admins* in the same hospital as the author.

h. Article likes API

POST|DELETE /api/articles/<uuid>/like/. There are no request parameters and there is no response body. This API is available for any authorized user except for *receptionists* and article *author*.

i. Comments creation

POST /api/articles/<article_uuid>/comments/. The fields are writable: *content*. This API is available for the following roles: *Admin*, *Doctor*, *Nurse*, *Policy Maker*, and *Patient.*

j. Comments update

PUT|PATCH /api/articles/<article_uuid>/comments/<uuid>/. The fields are writable: *content*. This API is available only for the author of the comment.

k. Comments deletion

DELETE /api/articles/<article_uuid>/comments/<uuid>/. This API is available for the author of the comment, for *super-admins* and for *admins* in the same hospital as the author.

M. Messaging

Threads API

Thread API represents a conversation. It has a set of members, where added messages will be broadcasted to all the members. It allows to add group chats in the future without much effort. However, there is no API for creating threads with more than two members yet. Also, Threads keep the time of the last update. Thread is updated when someone adds a message to it, when a new member is added, and when a member leaves the thread.

a. Representation

```
{
    "uuid": "thread identifier",

    "members": [
```

```
        // list of user representations

        // available fields: username, email, photo_url, first_name,
last_name, role, gender, hospital

        // hospital is an object with these fields: url_name, name

    ],

    "last_message": {

        // last message in the thread

        // see message API doc for details

    },

    "created": "date time when thread was created",

    "updated": "date time when thread was updated last time"

}
```

b. Starting a thread

POST /api/threads/private. This accepts an object with a single field *username* which should contain the username of a user to start the chat. This object creates a thread with two members: 1) the authorized user and 2) the user referenced in the request. If such a thread is already available, then nothing is created and a server just returns the existing value. So, you cannot have multiple conversations between two users. Lastly, the object returns a thread representation as described above.
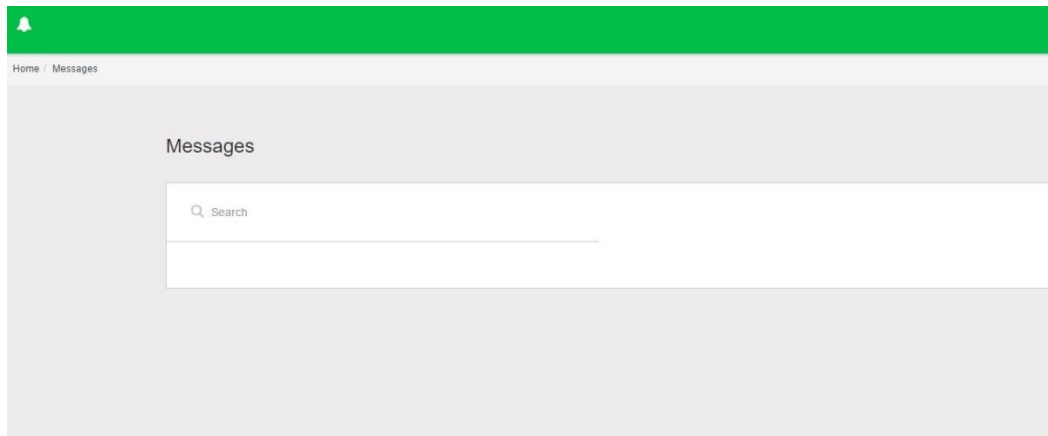
c. Listing threads

GET /api/threads/. This object returns a list of threads, when the current user participates.

d. Leaving a thread

DELETE /api/threads/<uuid>/. This removes the current user from the threads' members set. Threads are automatically removed from the database when all the members are left.

N. Messages API

    a.   Representation

<u>The Message is represented in the following response structure.</u>

```
{

    "uuid": "identifier",

    // "content" - it is regular message

    // "new-member" - new member joined to the thread; field
`content` will be empty, field `author` references joined user

    // "member-left" - member leaved to the thread; field `content` will
be empty, field `author` references joined user

    "type": "content" | "new-member" | "member-left",


    "content": "string if type == content",

    "author": {
```

```
    // author user representation

    // available fields: username, email, photo_url, first_name,
last_name, role, gender, hospital

    // hospital is an object with these fields: url_name, name

  },



  "created": "date time when message was created",

  "updated": "date time when message was edited last time"

}
```

Messages that are received from socket are represented in the following response body.

```
{

  "thread": "thread uuid",

  "received_time": "new value for thread.updated",

  // if message was created or edited:

  "message": {

    // Representation of the message itself, as described above

  }

  // if message was deleted:

  "message": {

    "uuid": "message identified",

    "deleted": true
```

```
        }

    }
```

b. Connecting to the socket

```
function(domain, port) {

    socket = new SockJS(domain + ':' + port + '/msg-listen');



    socket.onmessage = function(msg){

        // msg.data contains the message from the socket

    }



    socket.onclose = function(err){

        // try reconnect here

    };

}
```

Just after connection, a client should send the next message:

```
{

    "action": "authorization",

    "token": "pass auth token here"

}
```

This request performs authorization. If it fails, then the connection will be closed immediately. If a server does not receive this packet within 30 seconds, then the connection will be closed.

c. Load conversation history

GET /api/threads/<thread-uuid>/messages/. This object returns paginated list of messages for a specified thread. Current user should be a member of the thread.

d. Post message

POST /api/threads/<thread-uuid>/messages/.

This object accepts an object with a single field *content*. This creates a message of type "content" authored by the current user. The object returns representation of the created message.

e. Edit the message

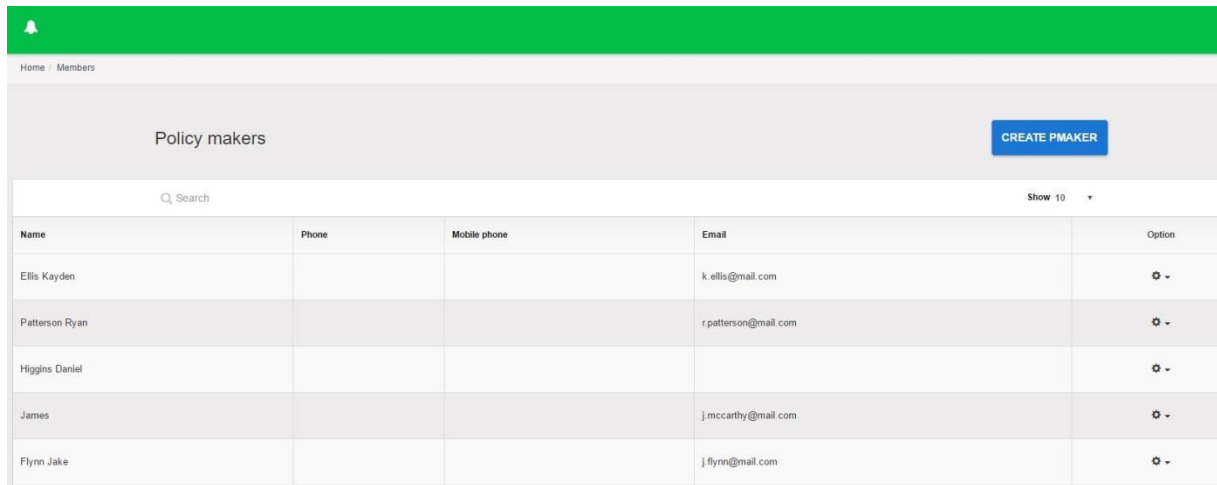PUT|PATCH /api/threads/<thread-uuid>/messages/<message-uuid>.

This is as same as a creation API. This API accepts an object with a single field *content*. The message should be authored by the current user and the message type should be "content". The message should be created no earlier than an hour ago. This returns the representation of the updated message.

f. Delete the message

DELETE /api/threads/<thread-uuid>/messages/<message-uuid>/.

This deletes the message. The message should be authored by the current user and the message type should be "content". The message should be created no earlier than an hour ago.

O. Policy maker's reports

a. Statistics API

Statistics engine divides patients into categories based on the follwoing parameters:

- Patient's current disease;
- Location;
- Gender;
- Hospital where the patient is bound to;
- Age interval.

Engine calculates the number of patients within each category once per day (i.e., it requires setup with crontab). Client can query the calculated statistics on per-day and per-month basis.

b. API

GET /api/statistics/.

The query parameters are:

disease - get statistics only for a specified disease, otherwise server will return total stats for all diseases. This accepts the disease UUID.

city - get statistics only for a specified city, otherwise a server will return total stats for all the world. This accepts the city UUID.

hospital - get statistics only for a specified hospital, otherwise a server will return total stats for all hospitals. This accepts the hospital UUID.

scope - *"day"* or *"month"*. It transfers to the server whether or not it should return stats for each day or only for last days of month.

last - how many points in the time will be requested. With *scope=day* returns stats for *N* last days, with *scope=month* - for *N* last months.

The response structure of this API is:

```
[

  {

    // how many patients are in this category

    "number": integer,

    // gender of patients in this category

    "gender": "M" | "F",

    // string that denotes the age interval for users in this category

    "age_label": string,

    // date when this stats entry was calculated

    "date": {

      "year": integer,

      "month": integer,

      "day": integer

    }

  }

]
```

There are some important notes:

1. There is no pagination. All requested entries will be returned at once and there is no wrapping object that holds the total count of entries, "result" array etc.

2. Items are unordered. Client side should order them by date to show the chart.

3. There are few entries for each date. These entries differ by age_label and gender. Client should group the entries by these fields.