Modelling Health Process and System Requirements Engineering for Better E-health Services: Focus on Diabetes in Saudi Arabia

By

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Fuhid Alanazi declare that this thesis is submitted in fulfilment of the requirements for the award of PhD in the School of Electrical and Data Engineering /Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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LIST OF PUBLICATIONS

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GLOSSARY

ASD	Autism spectrum disorders
ASMOG	Actor Service Object Means Goal
B2B	Business to business
B2C	Business to customer
BCM	Business Continuity management
BPR	Business process reengineering
Care	Coordination/homecare telehealth
CFIR	Consolidated Framework for Implementation Research
CEO	Chief executive officer
CeHRes	Centre for e-health Research and Disease Management
DFDs	Data flow diagrams
e-health	Electronic health
e-HIT	The e-Health Implementation Toolkit
EMR	Electronic medical record
EPR	Electronic patient records
ESNAP	Electronic Social Network Assessment Program
EU	European Union
GOMS	Goals, Operations, Methods and Selection
HP	Healthcare processes
ICT	Information and communication technology
IoT	Internet of Things
IT	Information technology
JADE	Java Agent DEvelopment Framework
KADIS	Karlsburg Diabetes Management System

MBJT	Model-based jobs theory
MDE	Model-driven engineering
m-health	Mobile health
NEHTA	National Electronic Health Transition Authority
NHS	National Health Service
PEHR	Patient electronic health record
PDA	Personal data assistants
PHP	Personalised healthcare pathway
PHS	Personal Health system
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RAHAH	Remotely Accessible Health Care at Home
SAR	Saudi riyal
SD	Standard deviation
SEM	Structural equation modelling
SMS	Short message services
SOA	Service-oriented architecture
T1D	Type 1 Diabetes
T2D	Type 2 Diabetes
UK	United Kingdom
UPMC	University of Pittsburgh Medical Centre
USA	United States of America
VHA	Veteran Health Association
VRUH	Virgen del Rocío University Hospital
WHO	World Health Organization
WHP	Workplace health promotion

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Abstract

This research is aimed to identify design and process engineering requirements for the implementation of an efficient and effective e-health-based personalised diabetes management in Saudi Arabia.

The incidences of obesity and diabetes are high and increasing in Saudi Arabia. The steadily increasing cost burden to the government and patients is a major worry for the Ministry of Health. Research has shown that e-health-based personalised diabetes management can reduce the cost burden to both the government and the patients without any reduction in the effectiveness of healthcare. However, there was no work on e-health models for personalised diabetes management in the Saudi context. This research addresses this need and thus justifies this endeavour. A review of the literature showed high potential for such applications.

Thematic analysis was done on the focus group responses. One of the themes identified was directly related to the modelling requirements and provided insights into the variables required for a comprehensive e-health self-care system.

Survey responses from 210 patients near King Abdulaziz Medical City, Jeddah, were statistically analysed. Findings revealed a higher likelihood of diabetes among women aged 25-50 with a bachelor's degree or higher. Most patients monitored blood glucose levels and adhered to medical guidance but didn't seek hospital advice. Diet control and exercise were also prescribed, but not followed by a majority. Abnormal conditions were rarely reported. Limited e-health facility availability and patient registration were noted, possibly due to inadequate awareness. Survey results on the effect of interventions on the reduction of blood sugar levels showed the highest reduction for the intervention of medication, followed by diet, and then exercise. The reduction was higher in the case of females and patients who were older than 50 years of age. Regression analysis resulted in significant predictive power only for exercise.

Based on the above results and literature, a list of design requirements for an e-health system for the self-management of Saudi diabetic patients was made. Four design options were also identified. What remains is designing these four options, pilot testing with small samples, and finalisation of the most desirable model from pilot test results with any improvements

required. The selected model can be taken for validation. After any further improvements required, the finalised model can be transferred to the Ministry of Health for gradual implementation across the country.

Chapter 1 – Introduction

1.1 Background

1.1.1 E-health in general

Information and communication technology (ICT) has many applications across various sectors such as agriculture, industry, and transportation. The health sector can also benefit immensely from applications of ICTs. These technologies can be used for improving the quality of care, like using electronic patient records (EPR). It facilitates the self-management of chronic diseases by the patients themselves. It also improves the healthcare accessibility of remote communities through telemedicine. All these come under the purview of e-health. The World Health Organization (WHO) defines e-health as "the use of information and communication technologies (ICT) for health" (WHO, 2019).

Eysenbach (2001, pp. 833) describes e-health as follows:

> "E-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment to networked, global thinking, to improve healthcare locally, regionally, and worldwide by using information and communication technology."

The author further notes that the business concepts of business to business (B2B), business to customer (B2C) and customer to customer (C2C) are applicable in the case of e-health in the following ways:

- B2C: The capability of patients to interact online with their healthcare systems.
- B2B: Improved possibilities for institution-to-institution transmission of healthcare data for the common benefit as evidence-based medicine; and
- C2C: New possibilities for communication and cooperation among similarly placed patients, especially concerning the self-management of chronic diseases.

This indicates that e-health has been implemented through different business models and in different sectors. Moreover, the term "e" in e-health does not stand for electronic alone, but many more "e"s. Eysenbach (2001) lists 10 "e"s related to e-health: efficiency, enhancing quality, evidence-based, empowerment, encouragement, education, enabling, extending, ethics and equity. As stated by Lupiáñez-Villanueva et al. (2018, pp. 165), "E-health tools provide a means to disseminate health information and education for both patients and health professionals and hold promise for more efficient and cost-effective care processes."

E-health has numerous benefits in the medical field. E-health systems increase the safety of the patients through saving their data at a secure level. Digital hospitals can establish better and more effective communication between hospital staff and patients by using e-health systems. Additionally, e-health systems can keep records of patients' medications, enabling patients to take their medicine on time. In an interview with Widén and Haseltine (2015), Henrik Ahlen stated that e-health can be used for meeting the challenges of the growing healthcare needs of increasing and ageing populations. They also observed that e-health can address the increasing costs and staff shortages impacting the increasing demands for faster and more personal access to healthcare. Most e-health applications are used for fitness activities and self-care (Widén & Haseltine, 2015). However, e-health is most beneficial for patients with one or more chronic illnesses. In many countries, this group of patients accounts for more than 75 percent of healthcare costs (Widén & Haseltine, 2015). Therefore, cost reductions through improved efficiency and quality will have a significant impact on national dimensions of healthcare.

Many e-health initiatives target patients with chronic diseases. CDC defines chronic group of diseases as "Chronic diseases are defined broadly as conditions that last 1 year or more and require ongoing medical attention or limit activities of daily living or both. Chronic diseases such as heart disease, cancer, and diabetes are the leading causes of death and disability and drivers of annual healthcare burden" (CDC, 2022) of countries. A statistical account of chronic diseases was provided by Hajat and Stein (2018) as given in Figure 1.1. The data in Figure 1.1 shows decreasing the disability adjusted life years and diabetes is one cause for it. Figure 1.1 of Hajat and Stein (2018) was based on GBD by IHME (2015).

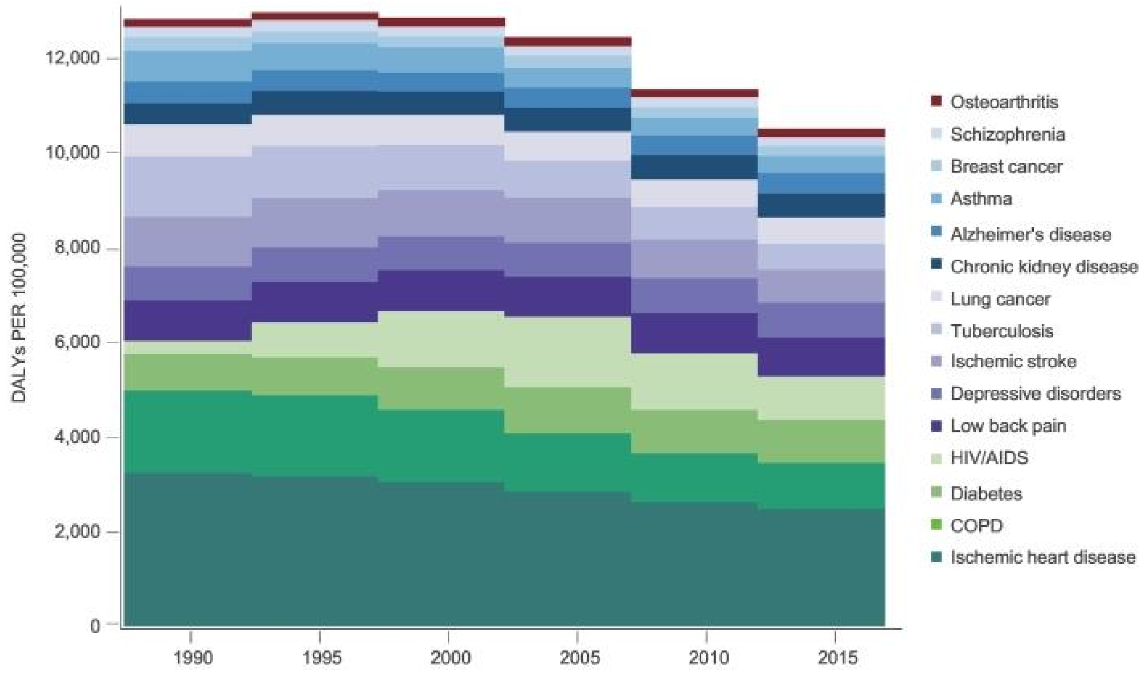

Figure1.1 Age-standardised DALYs (rate per 100000) for leading chronic conditions 1990-2015 (Hajat & Stein, 2018)

1.1.2 E-health for diabetic patients

One of the key chronic groups is patients affected by diabetes. Many countries have many patients with Type 1 (TID) or Type 2 (T2D) diabetes as a major chronic group. In Saudi Arabia, out of a population of 20.77 million, 3.852 million adults (18.5 percent) had diabetes (IDF, 2019). News (2019) cites Colliers' Report that in Saudi Arabia, 17.9 percent of adults had diabetes and 35.4 percent of adults were obese in 2019. Although there is consistency between these two estimates, 18.4% in 2017 and 17.9% in 2019 does not prove the increasing prevalence reported by Robert et al (2018) and others reviewed below. On the other hand, many other estimates show increasing prevalence of diabetes. The prevalence of diabetes is rapidly growing, as evident from an increase in the incidence rates among children and adolescents, especially for Type 1 diabetes (Robert, Al-Dawish, Mujammami, & Al Dawish, 2018). Robert et al (2018) presented estimates from different sources in their review. The estimates were 18.05 in 1990-1998 to 39.9 per 10000 children in 1999-2007 (Al Shaikh & Al Zahrani, 2016), 27.5 per 10000 children (Abduljabbar, Aljubeh, Amalraj, & Cherian, 2010), 29 per 10000 children (Habeb, et al., 2011). A meta-analysis of literature on prevalence of diabetes in Saudi Arabia by Jarrar, et al. (2023) showed the overall pooled prevalence in the general population to be 16.4% over the period of 2000-2020, with wide variations between estimations. The most recent (2022) report from IDF provides the prevalence estimate for diabetes among adults in Saudi Arabia as 17.7% (IDF, 2022). IDF projects an increase of this to 20.4% in 2030 and to 21.4% in 2045. A countrywide Saudi Arabian project conducted in 2001–2007 reported that, out of 11,874 out of 14,000 selected households and 45,682 children and adolescents surveyed, the prevalence rate was 109.5 per 100,000 individuals. Official registration of T1D cases is insufficient in Saudi Arabia. Hence, reliable official estimates of diabetes are difficult. The high prevalence rate of diabetes in Saudi Arabia shows that the management of diabetic patients and control of the disease is a serious problem.

One of the best ways to reduce the incidence of diabetes and to reduce the cost to patients and national healthcare burden is to equip patients so to manage the disease themselves with the support of a hospital. IDF estimates the total diabetes-related expenditure to the nation to increase from 7459.5 USD in 2021 to 9041.3 USD in 2030 and 10045.2 USD in 2045. The per patient cost for the same years are 1745.3 USD, 2115.4 USD, and 2350.3 USD respectively (IDF, Saudi Arabia Diabetes Report 2000-2045, 2021).

Personalised care management is possible by adopting e-health practices. According to Ceriello et al. (2012), many diabetic patients are unable to achieve the targeted treatment effects even with the help of advanced therapy against the disease and they are at risk of complications. A suitable solution to this problem is the personalisation of the management of diabetes adjusted to the individual profile of each patient. Adherence to the treatment therapy and other ingredients of care like daily lifestyle changes are possible when e-health with correct monitoring is implemented. The advantage of e-health is an increase in efficiency and remote access on an anytime basis. Both medical and economic benefits are possible through the integration of e-health into the personalised management of diabetes. The need for personalised care with community support was also reiterated by Tan et al. (2020).

Other methods to manage chronic illness through e-health systems are smartphone-enabled measuring methods and sensors attached to the patient for continuous monitoring. These are widely used and thus comply with the above assertion that personalised care is beneficial for the management of diabetes. Since smartphones are used by many people all over the world, they are a convenient portable platform for e-health applications for personalised diabetes management (Coughlin, 2017). The merits of mobile-enabled personalised diabetes management for addressing the twin threats of inadequate care and rising costs for both patients and providers are highlighted by Thestrup et al. (2012). Without addressing this issue, lost working days and labour shortages may cause serious economic development problems for countries.

Although digital care has numerous advantages, the results achieved so far have been only modest. Recognising this, Cahn et al. (2018) suggested that there needs to be a greater understanding of the barriers of digital care and that the needs of patients are yet to be identified and met. A better understanding of the barriers to digital care can help policymaker's strategies to address the issues related to them.

There are many readymade software programs for the use of e-health in diabetes management. One software program, the Karlsburg Diabetes Management System (KADIS), was tested and was found to be better than not having this system in the care model (Salzsieder and Augstein, 2011). According to Kaufman et al. (2016), the digital care of diabetes facilitates consumer engagement, behavioural change, and impact analytics. The successful adoption of e-health models by the pioneers of personalised diabetes management has motivated others to follow suit. Enabling health is more important in value creation than care delivery, and e-health practices enhance both.

A completely mobile diabetes management system for the complete home care of diabetes was developed, tested, and validated by Holopainen et al. (2007). The system integrates seamless and real-time patient–doctor communication, supported by patient electronic health records (PEHR) and nursing requirements. The main part of the system is a mobile platform that collects information from measuring devices wirelessly and a server platform that receives the collected data and transmits them to the current diabetes management system.

Kristoffer (2018), the chief executive officer (CEO) of Liva Healthcare, notes that medication interventions can easily be scaled up and distributed among patients. Changes in lifestyle, which is a very important part of diabetes management, are much harder to do. Diet and exercise are the main personalised interventions for patients with diabetes. These can reduce drug intake as sugar levels come down. Dedication and continuous effort are required for making long-term lifestyle changes to form new and lasting habits. For example, maintaining weight loss is far more difficult than achieving it. Another issue is that doctors often cannot check whether all their diabetic patients are following their advice. But it is possible to do this with e-health applications. Therefore, the gap between doctors and diabetic patients regarding compliance with advice on medication, diet and exercise can be reduced.

Kafalı et al. (2013) report on the development and validation of a personal health system (PHS) called COMMODITY12 that can help both doctors and patients to manage diabetes. This smart e-health environment consists of portable devices for ambient, wearable use by diabetic patients. The devices capture, monitor, and communicate critical physiological and other health-related parameters of the patient including physical activity and vital body signals. Intelligent agents interpret these data using expert knowledge to identify the current health status of the patient. The feedback information on the current health status with data can be either given to the patient directly from the device or through health professionals assisting the patient in diagnosis, treatment, and life management. It is neither possible nor desirable to do away with physician's help by using algorithm-based decision-making e-health systems, as has been observed by Kristoffer (2019).

The advantages of telemonitoring for the personalised management and control of diabetes are discussed in a review by Laurent et al. (2019). They find that improvements in blood glucose control, reductions in HbA1c and improvements in patients realising and accepting the seriousness of the problem all lead to better compliance with the treatment regimes. Some advantages include dietary and lifestyle changes, reduced impact on comorbidities, improvement in the quality of life of the patient, and improved accountability and feeling of responsibility by the patient. However, the extent of benefits obtained are not substantial.

Methods of personalised self-management of diabetes by patients taking control of their own health records are explained by the chair of the National Electronic Health Transition Authority (NEHTA) Steve Hambleton and the CEO of Diabetes Australia Greg Johnson (Hambleton & Johnson, 2015). The patient needs to register for e-health records to access the self-management tools. Then, the use of electronic health records gives the patient the ability to track their personal health information and review their progress over time.

The progress from diabetes care towards a cure for diabetes is aided by the discovery that lifestyle changes like diet and exercise can reduce blood sugar and thus reduce medication requirements. This approach requires personalised and sustained lifestyle adaptations for permanent change. To implement this, a systems approach is required. Such a system should include all relevant aspects. The relevant aspects are motivation, health literacy, empowerment and participation ensuring personalised diagnosis and diet, physical activity, and stress management. All these are facilitated by blended care and e-health.

According to Fagherazzi and Ravaud (2018), e-health has the power of a no-burden continuous monitoring of symptoms, physiological parameters, dietary and exercise behaviours, and social and environmental aspects around the patient. Wearables, sensors, smartphones, and online and digital technologies are the components of this system. It involves many stakeholders, including patients' relatives and friends, the e-health system providers, the community, social groups, the population at large, health professionals, health voluntary workers, healthcare providers, government departments, insurance and others connected with e-health services. The digitalisation of diabetes has impacted its therapy, prevention, management, technology, and research alike. It has become a part of health literacy.

Wong and Lam (2016) emphasise the collaborative care partnership between the patient and the healthcare professionals for the self-management of diabetes by patients. The central role is of the patient, who uses self-monitoring and self-care as a responsibility. The patient is empowered by the e-health system to play this role. The very first aspect is the knowledge of the patient regarding diabetes and its care. Adequacy of knowledge is related to the competence to make decisions by oneself or with the support of healthcare professionals, depending upon the need. Community nursing strategies in terms of educational programs, counselling intervention and home visits are examples of such patient–professional partnerships. Thus, there is a need and adequate justification for use of e-health solutions for the personalised management of diabetes.

1.2 The Status of Diabetes Patient Management Through E-health in Saudi Arabia

The high prevalence rate and the problem of the effective reach of diabetes patients in Saudi Arabia were highlighted in the previous section. In 2020, the Saudi Ministry of Health estimated that the average annual cost of diabetes treatment without complications is USD $2,600 per Type 1 diabetes (T1D) patient and about USD $2,000 per Type 2 diabetes (T2D) patient (Alanzi, 2018). Given these figures, the country's cost burden for diabetes treatment may be USD $6.5 billion in 2020. Presenting these statistics, Alanzi (2018) notes that policy deficits and scarce research on e-health systems for diabetes resulted in poor implementation of e-health systems at the hospital level. The e-health initiatives of the Saudi Ministry of

Health are limited to creating silos of health records and some service facilitations. Thus, any study on the modelling and implementation of e-health systems for personalised diabetes management in Saudi hospitals will be new research. The need to adopt e-health is increasing as the changes in demographics, work habits and lifestyle contribute to rapid increase in the prevalence of diabetes in Saudi Arabia. There are only some scoping papers on this topic, like those of Aldahmash et al. (2019) and Belcher et al. (2019). This research deals with e-health modelling at the implementation level in a hospital. Based on the above background information, the research problem, research question, aims and objectives are formulated as shown below.

1.3 Research Problem Identified

The above background indicates the urgent need for studies on the personalised e-health management of diabetes among Saudi patients. This urgency is due to the high prevalence and rapid rise in the prevalence rate of diabetes among the Saudi population and the rising cost of treatment affecting the national economy. This is especially important for Vision 2030 (Saudi Arabia, 2016), which is an ambitious economic and social overhaul plan of Saudi Arabia that is being implemented. Therefore, the overall aim of this study was to seek methods of reducing the prevalence of diabetes in Saudi Arabia using an e-health-based self-management system for diabetic patients.

1.4 Research Questions

To address the above research problem, the following research questions were formulated to answer the question-

Main research question:

- What are the design requirements modelling for e-health based personalised diabetes management systems in Saudi Arabia?

Detailed research questions:

1. What is the current situation of e-health in Saudi Arabia? (RQ1)
2. What are the current design requirements, models, and theories in the literature? (RQ2)
3. What is the role of design requirement engineering and process modelling in the context of health improvement? (RQ3)

4. What is the role of stakeholders in identifying design requirements modelling for personalised diabetes management systems in Saudi Arabia? (RQ4)

This research has four main objectives:

1. To understand the current issues and challenges of e-health systems and requirements for the literature and survey findings.
2. To identify and analyse design requirements from stakeholders' perspectives (patients, healthcare practitioners and e-health experts) in Saudi Arabia.
3. To provide design requirements and parameters for e-health-based personalised diabetes management in Saudi hospitals.
4. To enhance and evaluate the awareness and understanding of e-health design requirements, which could benefit e-health developers and academics.

1.5 Achievement of the Objectives

The research objectives are achieved using the following methods:

1. Literature and the results of the survey responses were used to understand the current issues, challenges, and design requirements associated with the current e-health systems in Saudi Arabia. This also assisted with the preparation for the focus group sessions.
2. Focus group interviews, which comprised meetings with Saudi Arabian stakeholders (patients, healthcare practitioners and e-health specialists), were part of the qualitative research method. This strategy aimed to gather precise details and responses related to the requirements of engineering.
3. This research objective aimed to identify and understand how e-health systems are being developed, the challenges connected with this process, and the experiences and perspectives of stakeholders. As a direct consequence of this, a list of potential requirements for systems engineering was proposed. Some possible e-health self-management models for diabetes were proposed.
4. This research identified what aspects of Saudi Arabia's e-health scenario are lacking by analysing the results of quantitative surveys and focus group assessments. It then provided recommendations for improving the diabetes healthcare system in Saudi Arabia. The proposed models could be tested, and the most suitable ones could be adopted for a pilot study and extended to the entire nation.

1.6 Contribution

The potential contributions of this research are:

1. According to the literature review, at the time of writing this thesis, no explicit models or processes have been applied to determine what design requirement modelling is essential for personalised diabetes management systems in Saudi Arabia.
2. As per the literature reviewed previously, most studies on e-health in Saudi Arabia have concentrated on the technical issues associated with e-health systems. In addition, a few studies have evaluated how personalised diabetes management could help healthcare professionals enhance patient care and disregard users' core roles. It is observed that previous researchers paid little effort to employing qualitative or mixed approaches to understand engineering requirements.
3. Consequently, this research addresses a gap in the current literature by identifying and analysing design requirements from stakeholders' perspectives in Saudi Arabia, a topic that has not been previously investigated.
4. The findings of this study may provide the government with a basis to accomplish its 2030 vision regarding the design of new and innovative e-health systems, particularly diabetes management systems.
5. This research could benefit e-health systems developers and theory/model developments in the information systems research area.
6. The findings of this study could be used more broadly in other nations by considering the cultural and regulatory requirements.

1.7 Unique characteristics of Saudi Arabia necessitating the need for customised model for diabetes patients of the country.

Evason (2019) lists the uniqueness of Saudi Arabia in terms of tradition, conservatism, modernisation, industrialisation, community interdependence, honour (Sharaf), protectiveness (Gheera) and modesty. The country has a fundamentally traditional and conservative culture. Islamic culture deeply influences the society. It guides people on social, familial, political, and legal lives. The Saudi people have a strong moral code. Their cultural values are based on hospitality, loyalty, and a sense of duty to support their community. They are sensitive about their personal honour and integrity. Despite all these traditionalisms, the country is highly modernised and industrialised. Now, wanting to be seen as a modern country, the country is undergoing many reforms on personal, domestic, political, and legal fronts. There is strong gender separation in the country, leading to a perception of discrimination against women. This is gradually fading as the influence of clerics on political decisions is declining. Many such social norms of behaviour are changing gradually. The average Saudi citizen is proud of his country's strong Islamic culture. The gradual shift to modernism and the declining influence of the clerics are indicative of the preparedness of Saudi people to accept and adopt modern technologies like e-health.

1.8 Summary

In this chapter, the scope and status of e-health-based personalised diabetes management systems for implementation in Saudi Arabia were examined. It was found that little work in this area has been done in Saudi Arabia. This justified the urgent need to design and validate an e-health model for implementation in a hospital due to the rapidly increasing incidence of diabetes among the Saudi population and the increasing costs of treating diabetes patients impacting the national economy.

Based on the above evaluations, the research problem, questions, aim and objectives have been listed above for this thesis. This section provides an overview of the thesis, as shown in Figure 1.1. The thesis has a total of seven chapters.

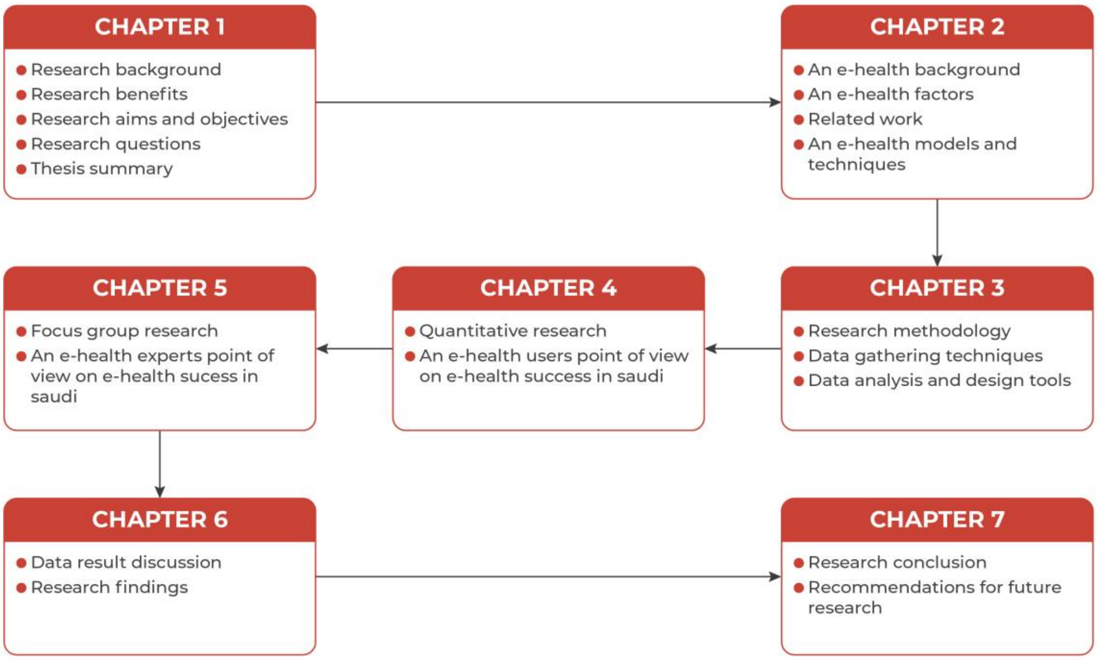

Figure 1.1: Thesis summary

The next chapter (Chapter 2: Review of Literature) reviews the available literature on the topics relevant to this research. Chapter 3: Research Methodology provides a detailed description of the methods followed for the collection and analysis of the data required to achieve the aims of the thesis. Chapter 4 describes the focus group results for e-health models and techniques and includes an analysis of the current models and their suitability for the Saudi healthcare context. Chapter 5 provides the survey results obtained from a survey of e-health users in Saudi Arabia and a quantitative analysis of e-health. Chapter 6 discusses the importance of alignment between information systems and e-health and evaluates the factors among e-health experts based on the findings. Chapter 7 outlines the conclusions derived from the results above and assesses this study. It also encapsulates the key findings and the recommendations for future research directions. The limitations of this research are also discussed in this chapter.

Chapter 2 – Literature Review

2.1 Introduction

In recent years, electronic health (e-health) has attracted much attention in both industry and academia. There has been significant progress in development and research in the e-health discipline (Absolom et al., 2021; Ahmad, Singla, & Giri, 2021; Alfadhel, Liu, & Oderanti, 2017; Amin et al., 2020). However, e-health services are useful only when citizens can use them. Few techniques and tools exist to assess customers' capability for employing e-health. About 40 percent of Canadian and Americans adults were found to have very little or basic learning levels, suggesting that e-health assets are likely to be unavailable to large proportions of the population of those countries (Price et al., 2016). Using information systems and information technology for health environments involves e-health literacy, which includes the capability to use computers for reading, searching for information, writing emails and communication (Absolom et al., 2021; Ahmad, Singla, & Giri, 2021).

The background and the origins of e-health can be traced to the early 1990s, a time when internet technology and related applications saw remarkable growth in the public perception of e-health. From the origin of the discipline of "e-health," there have been many "e-terms" proposed in software application and development. Researchers and developers have generally used the term "e-health," since it utilises not only the technology of the internet, but also information and communication technologies (ICTs) and web applications in the health sector (Aljohani, Alfaidi, & Zahid, 2021; Amin et al., 2020; An et al., 2021; Arfi, Nasr, Kondrateva, & Hikkerova, 2021). An e-health system incorporates the capability of individuals, healthcare service providers, and other information technology participants to enable healthcare services and system functionality to interconnect and share health and routine information, support and services (An et al., 2021; Arfi et al., 2021; Atanasovski et al., 2018; Baek et al., 2021). Additionally, the use of ICTs and web-based applications has improved expanding the definition and introduction of e-health to other services and functions, like providing services to administration staff and educating them about the e-health system (Atanasovski et al., 2018; Baek et al., 2021; Barambones, Moral, Ferre, & Villalba-Mora, 2020).

The importance of e-health is evident in both developing and developed countries. E-health developments include the introduction of electronic health data, patient records, information technology-assisted e-health systems and medicinal information systems and databases. They have altered the healthcare business and other related industries. They have the potential of further enhancement of healthcare in the future. E-health has improved the environment of healthcare and represents a platform for delivering health understanding and sustaining organisational functions (An et al., 2021; Arfi et al., 2021; Atanasovski et al., 2018; Baek et al., 2021). The idea of e-health has established new and effective techniques for delivering health and healthcare facilities to the community. Simultaneously, it has assisted in holding public and private health service providers (such as physicians, professionals, organisations, and healthcare providers) accountable for always providing health facilities on a mandatory basis to individuals and on all days. E-health has also been of interest to international organisations like the European Union (EU) and WHO (WHO, 2019). These developments have encouraged academic investigators and software application developers to intensify the progression of e-health. In the process, they tackle various issues related to it and delivering more well-organised and automated healthcare applications and solutions to health problems.

The phrase “e-health” has been described and defined in many ways. Scientists have produced several definitions of e-health, attempting to generate a “shared meaning” amongst e-health organisations and the researchers who use this terminology (An et al., 2021; Arfi et al., 2021; Atanasovski et al., 2018; Baek et al., 2021). This aim might be better met by examining a range of proposed meanings encompassed by the term to acquire a clear knowledge of e-health system use. In some academic research, e-health has been recognised as an oversight phrase, with meanings depending on the intent and circumstances in which the phrase is used (Atanasovski et al., 2018; Baek et al., 2021; Barambones et al., 2020). Preceding 1999, the phrase “e-health” was hardly utilised, but now it has become a general buzzword utilised to differentiate not just “internet medicine” but also almost everything associated with web-based e-health systems and ICTs.

This chapter conducts a literature analysis that is associated with the aims and objectives of this thesis. The chapter starts by introducing the motivations behind the field of e-health before examining e-health definitions and the tools and techniques of health and its background. A thorough discussion of various e-health methodologies is presented. The chapter also discusses process modelling in the context of system requirements engineering and e-health. For this purpose, both a general review and a systematic review of literature has been done in this chapter.

2.2 Background of e-health

E-health is a comprehensive term integrating any area that unites information systems and healthcare to enhance competencies and decrease resources and costs. The goal of e-health is to justify treatment choices to enhance patient protection, privacy, and consequences. The implementation of information systems and other competing applications in e-health care began in the 1990s. At that time, only supercomputers and related information technology applications were available and only the most important clinics in advanced countries could utilise these e-health machines and devices, with families and individuals paying for these services. Recently, there is a significant uptake of the customised delivery of health-associated information among the health specialists and information systems and information technology professionals (Cavero-Redondo et al., 2021; Chang, Zhang, & Gwizdka, 2021; Cheng, Elsworth, & Osborne, 2021). The results from the e-health machines and devices were usually encumbered with technical and supercomputer application errors (e.g., unable to retrieve information). The failures of this early age of information technology in healthcare were typically due to many reasons. These include the lack of dynamic support from clinic administrators and higher management, the absence of continuing funding, and the absence of evidence and capability for the design and service of mechanical supercomputer systems (Cavero-Redondo et al., 2021; Chang et al., 2021; Cheng et al., 2021; Chomutare et al., 2021).

In the 1990s, the internet and related technology became publicly available, and e-health was launched in the field of information and software application development. E-health established the benefits of using the internet and other related technologies in the healthcare area and it was widely utilised because of its capability to enable everyday tasks and processes. It provided new opportunities for patients, healthcare providers, healthcare suppliers and others to connect and communicate about health and everyday life information and to provide essential services and assistance through internet technologies (Chomutare et al., 2021; Chowdhury, Hossan, Shahjalal, Hasan, & Jang, 2020; Ehn, Derneborg, Revenäs, & Cicchetti, 2021; Gerli, Arakpogun, Elsahn, Olan, & Prime, 2021). Over time, e-health shifted from completely being the application of the internet to healthcare to utilising various forms of communication technology and information to enhance healthcare facilities (Ehn et al., 2021; Gerli et al., 2021; Girgis et al., 2017). Moreover, many scholars pointed out that e-health shows the ability of communication and transmission technology to improve and accelerate the advancement of healthcare facilities (Girgis et al., 2017; González, Canós, Norris, & Abbas, 2018; Haase et al., 2021; Heinsch et al., 2021).

After the 1990s, the aims of e-health progressed from utilising the technology of the internet for distribution purposes to playing a major role in relieving significant healthcare difficulties. The population is growing populations with an associated increase in numbers of patients. This, along with the growth prospects of health facilities and value care, creates problems in the supply and development of e-health information systems for societies all around the world. The effective application and development of e-health information systems and methodologies provide some solutions to this problem. For instance, through e-health, the price-efficiency of wellbeing services has increased (Girgis et al., 2017; González et al., 2018; Haase et al., 2021; Heinsch et al., 2021). Likewise, there has been a reduction in examination expenses, which is not only advantageous for patients, it also allows e-health businesses to improve health care (González et al., 2018; Haase et al., 2021; Heinsch et al., 2021). The benefits of using e-health have also improved reporting characteristics, such as allowing information conversation and exchange, health education and care management (González et al., 2018; Haase et al., 2021; Heinsch et al., 2021).

With the rapid developments in ICT and the web, e-health research and development can work with patients with significant health issues. Research and development in e-health have resulted in innovations in e-health information systems for hospital patients, health experts, health guarantors and sponsors, policy suppliers, and other participants. These innovations incorporate, although they are not restricted to, decreasing anxiety in people's day-to-day lives, alleviating diseases and improving health understanding (Kanwal, Anjum, & Khan, 2021; Kunnappilly, 2021; Kyriacou et al., 2021). E-health scientists have also considered the exceptional characteristics of health, medication and making advances in healthcare information technology equipment in terms of mobility, observation and environment awareness (Kanwal et al., 2021; Kunnappilly, 2021; Kyriacou et al., 2021; Levy et al., 2021). The latest forms of e-health systems has presented new e-health tools and applications that not only use internet-based technologies and applications but also comprise electronic health data (Kunnappilly, 2021; Levy et al., 2021; Oderanti, Li, Cubric, & Shi, 2021; Palac et al., 2018). It also includes asynchronous health care interaction, telemedicine file away services and communication, individual wearable and transportable interaction to monitor e-health services, cognitive e-health information systems (Kunnappilly, 2021; Levy et al., 2021;

Oderanti et al., 2021; Palac et al., 2018; Piad-Morffis et al., 2021; Pohn, Dolezal, Legenstein, Polanz, & Schuh, 2019), and mobile e-health. These tools and several other ICT and web-based devices ensure that e-health is a fascinating investigation area for both the health industry and academics. This type of innovation support enhances the ability of healthcare suppliers, who can therefore deliver enhanced customer services (Kunnappilly, 2021; Levy et al., 2021; Oderanti et al., 2021; Palac et al., 2018; Piad-Morffis et al., 2021; Pohn et al., 2019).

2.3 Awareness of e-health

Academics and researchers are now cognisant of the numerous research opportunities and positions through which e-health could be further employed and benefits obtained. Hence, they have focused on e-health information system application groups that can be or have been implemented. For e-health to be successful and to improve the development and implementation of e-health information systems, it is vital to accurately identify various characteristics of the idea of e-health. These include the motivations for e-health, the characteristics of e-health, what e-health is and why researchers should do e-health research. Some researchers note that the awareness of e-health and its differing viewpoints, areas, and challenges offer great motivation in the field of e-health (Pouls et al., 2021; Reichold, Selau, Graessel, Kolominsky-Rabas, & Prokosch, 2021; Scheibner, Sleigh, Ienca, & Vayena, 2021; Shabaya, 2019).

In the subsections below, various definitions of e-health and a thorough interpretation of the term and its current methodologies in connection with information system engineering and software engineering are reviewed (Pouls et al., 2021; Reichold et al., 2021; Sahi, Lai, & Li, 2021; Scheibner et al., 2021; Shabaya, 2019).

2.3.1 Definition of E-health

The term e-health has been defined by many academics and researchers. Prior to 1999, the phrase e-health was not widespread. Currently, this phrase seems to be serve as a “buzzword” that is utilised to describe not only technology-based health care and internet medicine but also everything related to the combination of health, medicine and ICTs (Shabaya, Ateya, & Wanyembi, 2018; Stavropoulos et al., 2020; Stephanie, 2017; Sun, Zhang, Shen, Zhao, & Zhang, 2021). The term is also used in various ways in scholarly literature. Many scholars have published research in this area and some of them note that the term is not immediately distinct from that of the broader healthcare cases and health intelligence fields (Stephanie, 2017; Sun et al., 2021; Tomashchuk, Li, Van Landuyt, & Joosen, 2020).

In a review paper, Oh et al. (2005) conducted a thorough overview of all prospective explanations and definitions of electronic health or e-health. The authors identified 51 definitions of e-health, but they note that more almost certainly exist. They find the phrase "e-health" is frequently employed by academic researchers, individuals, associations, e-health specialists, and health organisations. The literature review conducted in their paper does not provide a precise description of or define a clear process of describing the phrase e-health. Some researchers claim that stamping a precise definition on a term such as e-health is like stamping a precise description and definition of the web (Tomashchuk et al., 2020; Tsiounia, Dimitrioglou, Kardaras, & Barbounaki, 2019; Vizitiu et al., 2020).

The objective of discovering a precise meaning and definition of e-health is to enhance the technique of interaction among scientists and health organisations that make use of this phrase. This objective might be better achieved by reviewing the range of proposed meanings encompassed by the term to provide a clear understanding of its use (Vizitiu, Bîră, Dinculescu, Nistorescu, & Marin, 2021; Weber & Costa, 2020; Yang et al., 2021). It is critical to note that the phrase e-health has been recognised in several different areas of e-health and thus its particular significance alters according to the intent to which the phrase is applied (Shabaya, 2019; Shabaya et al., 2018; Stavropoulos et al., 2020). E-health has been specified in several separate methods and scientists have provided numerous definitions of e-health. The most cited of these definitions is that of Eysenbach (2001, pp. 883), cited in the Introduction chapter above.

This research agrees with this definition for the following two reasons. Firstly, the definition includes all features of e-health; for example, what the e-health system should do, how the e-health system should solve health-related problems, and the design of an e-health system in the context of the health sector. Secondly, it appears to be broad enough to be utilised for the swift development of the vibrant ecosystem of information technology in the context of better health services. Table 2.1 summarises some of the other important definitions of e-health.

Table 2.1: Definitions and descriptions of e-health.

Author/s and year	Definition of e-health and description
(Bouras et al., 2020)	E-health is defined as the process of developing information systems in the context of health. It is a system that uses information and communication technologies to facilitate and enhance wellbeing and healthcare facilities
(Knitza et al., 2020)	The training of medicine adopted by mobile devices; for example, computers, tablets, and smartphones.
(Bouras et al., 2020)	Identity management is a crucial element in the e-health information system therefore, the term "e-health" is defined as evolving technology that can achieve contracts of transactional health-related data states in a distributed way.
(Mitchell, 1999)	E-health refers to every type of health care through information technology applications that are distributed over the internet, varying from informational, learning and industrial services of products to direct facilities accessible by specialists, non-professionals, businesses or consumers themselves. E-health comprises a diversity of medical activities that have conventionally distinguished tele-health, although distributed through the technologies related to the Internet. Simply stated, e-health is making wellbeing services more effective while permitting patients and experts to do the earlier impossible.
(Mitchell, 1999)	E-health is newly emerged terminology that is needed to explain the collective use of automated communication and applications of technology in the health area.
(D'Urso, De Giovanni, & Spagnoletti, 2013)	E-health is a protection phrase, describing the joint usage of automated communication and applications of technology in the health area, and likewise the usage of digital transmission of data, data storage and repossessed automatically for scientific, instructive, and managerial purposes, both at distance and at the local site.
(Sneha & Varshney, 2006)	E-health is the use of information and interaction technologies throughout the whole range of purposes involved in the preparation and transport of health care.
(Jakovljević) (2020)	E-health is the purpose of the technology of the internet or other automated media by hospital patients, health employees, and the community, to distribute or provide entrance to health and daily life information or public services.

Author/s and year	Definition of e-health and description
(Harrison & Lee, 2006)	E-health refers to the equipment utilised for medical, informative, investigative, and managerial objectives, both at the regional site and through wide geographical regions.
(Watson, 2004)	E-health means integration and synchronisation of the technologies related to the internet in the field of health care.
(Sternberg, 2004)	E-health is an emerging business model which uses technology to support healthcare suppliers in compassion for patients and offering services.
(Wyatt & Liu, 2002)	The usage of the internet and related technologies by way of the public, wellbeing workers, and others to gain access to health and information on people's lifestyle, support and services and support.
(Deluca & Enmark, 2000)	E-health is the automated interchange of data related to health around business organisations, even though every health care is fundamentally e-health.
(Tieman, 2001)	E-health is all about electronic or digital services to healthcare organisations.

2.3.2 E-health Motivations and Challenges

E-health revolutions like the development of automated health data records and recommendation systems based on technology and health records, are altering the wellbeing industry and raising expectations for the future. The tools and techniques in information technology-based applications encourage health care and deliver wellbeing information to the community and technical information to health experts (Piad-Morffis et al., 2021; Pohn et al., 2019; Pouls et al., 2021; Reichold et al., 2021). They suggest a program for distributing and delivering health understanding and maintaining organisational roles.

Additionally, like in other businesses, web, information systems (IS) and ICT tools have altered the landscape of healthcare management. In the field of IS, e-health has established new and effective techniques to offer health and healthcare facilities to the public. Additionally, it presents a variety of public services that overlap medication, supercomputers, networks, and data science (Piad-Morffis et al., 2021; Pohn et al., 2019; Pouls et al., 2021; Reichold et al., 2021). Technical innovations in e-health systems enable private participants (e.g., specialists, physician associations and healthcare suppliers) to offer health facilities mandatorily in people's everyday life (Shabaya, 2019; Shabaya et al., 2018; Sneha &

Varshney, 2006; Stavropoulos et al., 2020; Stephanie, 2017). The usage of web and information technology tools in the wellbeing area helps the accumulation, evaluation, and storage capacity of health information of all types (Arfi et al., 2021; Atanasovski et al., 2018; Baek et al., 2021; Barambones et al., 2020). It offers access to the newest discoveries and guarantees the ability of many deferential physician companies and healthcare suppliers to align (An et al., 2021; Arfi et al., 2021; Atanasovski et al., 2018). ICT-based wellbeing devices and tools have a substantial role in helping avoidance, analysis, therapy, health checking and daily life management (Bouras et al., 2020; Cavero-Redondo et al., 2021; Chang et al., 2021). Additionally, they improve the administration of health understanding, with innovations in wellbeing research being sponsored through e-health (Heinisch et al., 2021; Jakovljević; Kanwal et al., 2021).

In addition to the availability of new scientific solutions for health stakeholders, e-health information systems have significantly enhanced the value of life of many people by providing them with the care they require (Kunnappilly, 2021; Kyriacou et al., 2021; Levy et al., 2021; Mitchell, 1999). Growing populations, heightened expectations of good quality healthcare facilities and a higher quality of life have raised concern among educational scientists, software application developers and ICT suppliers. As the world population expands, the number of individuals demanding healthcare, including mentally ill people, elderly, disabled and habitually ill patients (Shabaya et al., 2018; Sneha & Varshney, 2006; Stavropoulos et al., 2020) also increases. E-health improvements could be employed to enhance healthcare for the world's varied inhabitants (Kunnappilly, 2021; Kyriacou et al., 2021; Levy et al., 2021; Mitchell, 1999). In recent years, e-health information systems have also developed as a key part of healthcare for persistently ill patients with the intention of saving costs (Shabaya et al., 2018; Sneha & Varshney, 2006; Stavropoulos et al., 2020). However, such developments cannot push forward until all legal, privacy and ethically associated problems and issues are tackled. The highest challenge and problem are generating evidence that e-health could improve wellbeing system presentations, coordination, and performance (Reichold et al., 2021; Sahi et al., 2021; Scheibner et al., 2021; Shabaya, 2019).

In the context of e-health's issues, these may act as barriers or challenges to the implementation of an effective e-health system and therefore determine the model and requirements in specific contexts. Some problems in this regard have been identified by researchers. E-health technologies can facilitate improved communication and information-sharing among health professionals, patients, and researchers, leading to improved quality and effectiveness of care. However, inefficiencies in the procurement of supplies and inadequate use or lack of resources affect the economic performance of health services. The common problems ailing the e-health industry are listed by van Limburg et al. (2011):

- Innovations are slow due to the problems of current financial structures.
- Inadequate healthcare legislation acts as a barrier to the modernisation of healthcare.
- The reluctance of involved parties leads to slow uptake.
- Too much focus on engineering-driven solutions for e-health technologies.
- Fragmented implementation of e-health technologies with poor scalability.
- High levels of complexity due to many stakeholders and dependencies.
- Inadequate studies on the cost-effectiveness of e-health technologies; and
- Focus only on clinical evidence in terms of health outcomes leading to the failure to recognise other factors that determine the success of e-health technology.

2.4 Modelling e-health Environment and e-health Models

2.4.1 What is Health Process Modelling?

The concept of health process modelling has been described by Ruiz et al. (2012, pp. 75-87) as any system development process covering the system's lifecycle from analysis through design, specification, implementation, testing, certification, and maintenance. It must be based on business' needs by running an appropriate business process. Due to its ability to describe business processes in a way understandable by both humans and machines, business process modelling is widely used in any kind of enterprise. This also holds for the medical domain. The objectives driving this procedure range from the economic aspects of process optimisation through to the increase of transparency and exchangeability of data and knowledge up to the assurance and certification of quality. The development and standardisation of meta-languages to formally describe and model business processes as well as solutions for the execution of model files enables the reuse of those models for different purposes with theoretical and practical implications.

A business process model described by Rolón et al. (2008) is reproduced in Figure 2.1. The authors describe the business process model for healthcare in detail.

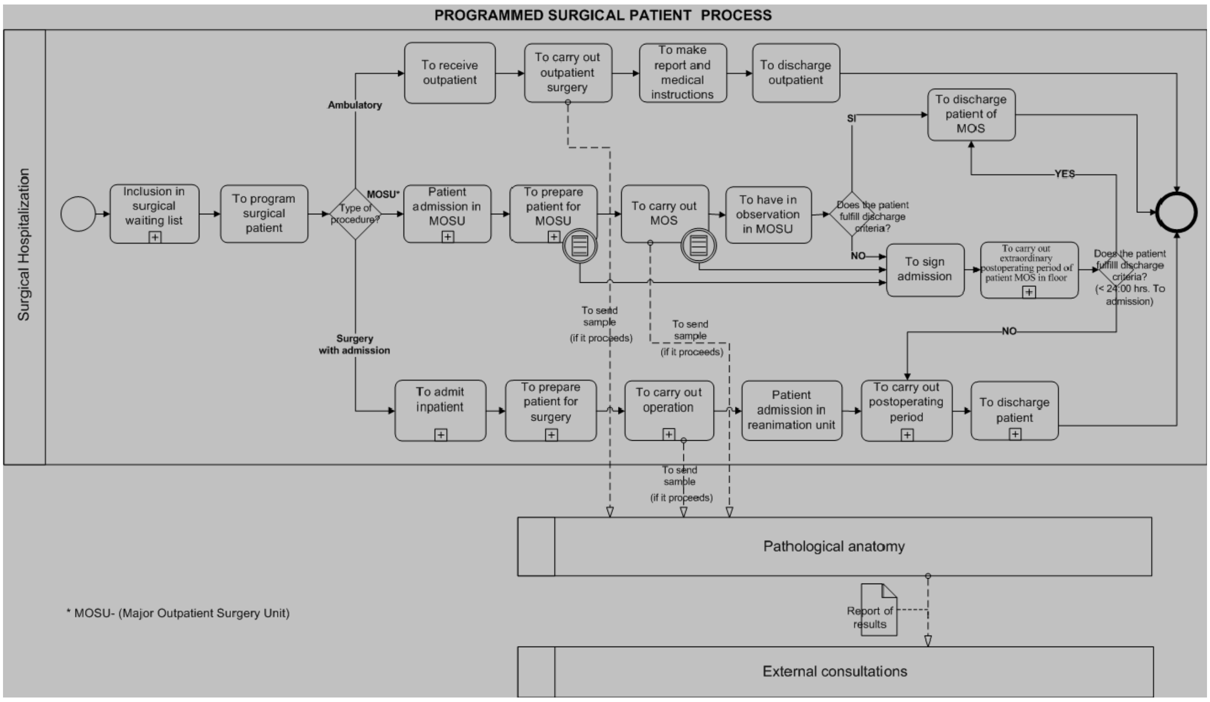

Figure 2.1: A programmed model for the surgical patient process.

Source: Rolón et al. (2008)

Once the process model has been made (business or other types), the requirements for each step of the process need to be determined and, on that basis, engineering for meeting these requirements needs to be done. Here, the word "engineering" means designing a system using scientific principles which can deliver the desired outcomes. Thus, the need for requirements engineering arises. Requirements engineering is explained in the following section.

2.4.2 System Requirements Engineering and Modelling an e-health Environment

Technopedia (2022) refers to requirements engineering as "the process of conforming engineering designs to a set of core software requirements. This is critically important for creating accurate results in software engineering." Requirements engineering is also known as requirements analysis.

The process of requirements engineering was diagrammatically presented by Elgabry (2016), as shown in Figure 2.2.

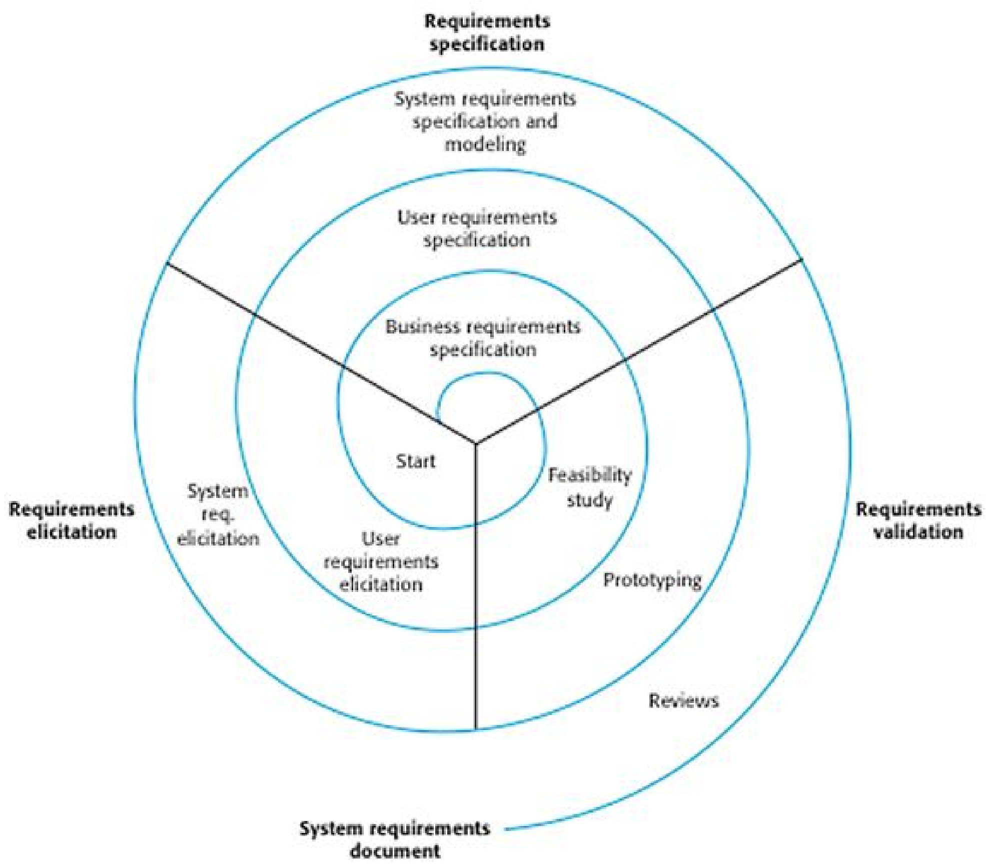

Figure 2.2: Requirements engineering process

Source: Elgabry (2016)

Combining the two concepts of healthcare modelling and requirements engineering, the requirements identified from a model are met through proper engineering processes for delivering quality care effectively, efficiently, and economically. In this research, the aim is to enhance e-health systems through modelling and requirements engineering. The above approach to combine the two concepts can be beneficial to address the aim of this research. Studies that have reported on these aspects are reviewed in the following sections.

2.4.3 e-health Models and Research Gap

One of the research questions outlined previously was "What is the role of design requirement engineering and process modelling in the context of health improvement?" The Ministry of Health in Saudi Arabia described its current e-health activities (MOH, 2019) using the diagram reproduced in Figure 2.3. It is noteworthy that both short-term and long-term activities and targets and all stakeholders have been included in this strategy.

Since it is not possible to include all the components of Saudi Arabia's national e-health strategy in this research, only the e-health aspects dealing with diabetic patients are being taken up here. The high prevalence of diabetes in Saudi Arabia calls for a multipronged approach to control its incidence gradually over a reasonable time (Alharbi, 2018). The system components of diabetic care on a personal and community basis were described by Alharbi (2018). By incorporating the specific conditions of diabetes management in Saudi Arabia, the above research question can be made more specific.

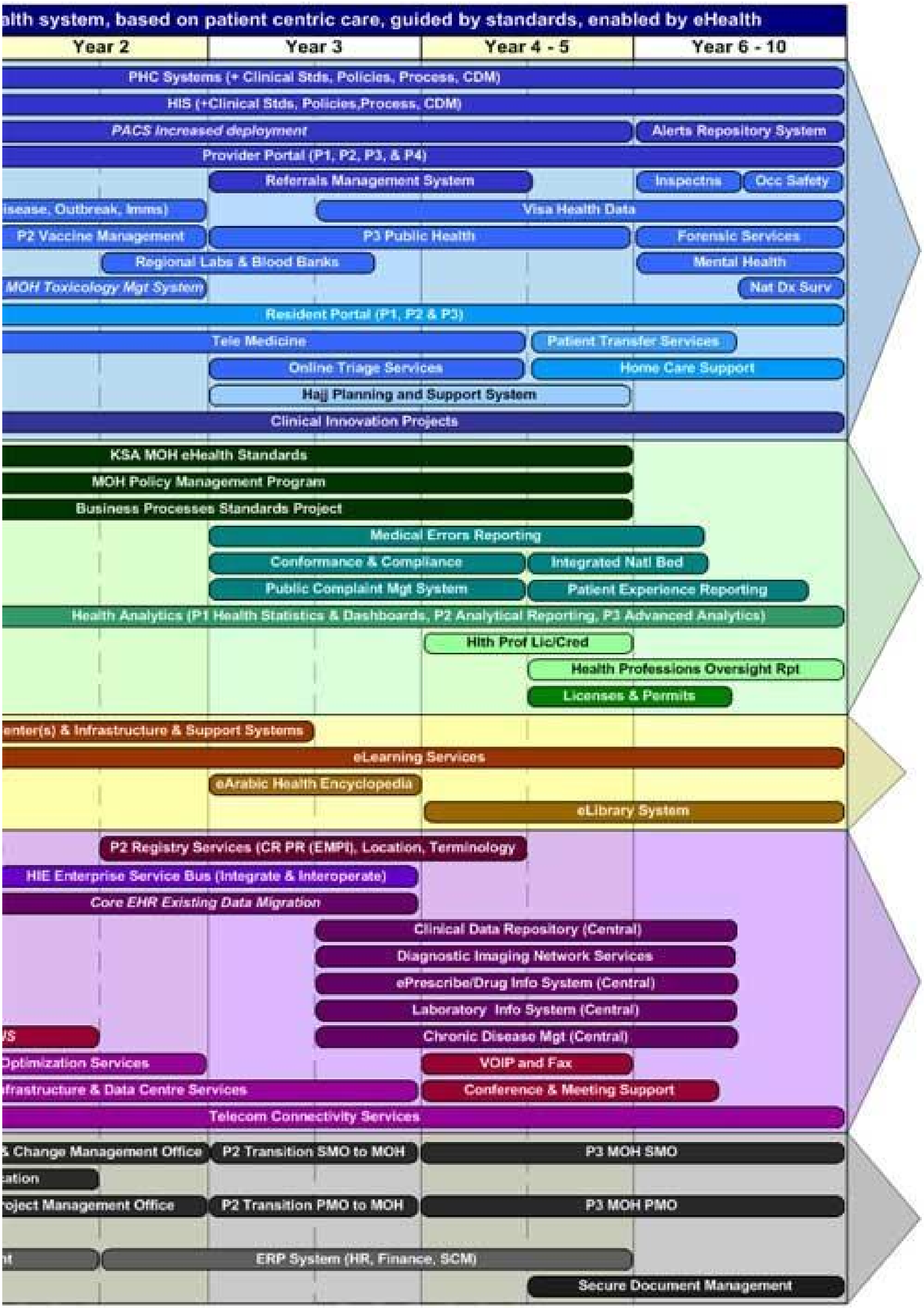

Figure 2.3: A national e-health strategy proposed by the Ministry of Health Saudi Arabia

Source: MOH (2019)

Different researchers suggested many models of personalised health plans for diabetic patients. For example, Ceriello et al. (2012) proposed a six-step cycle for personalised diabetes care and the collaborative use of structured blood glucose data. To improve process efficiencies and allow remote access, e-health solutions can be used. Doctors can use decision support tools and algorithms for therapeutic decisions based on individual patient profiles. A cloud-based diabetics care model was proposed by Thestrup et al. (2011). The diagram of this model is reproduced in Figure 2.4. The e-health components occur at all levels in this model.

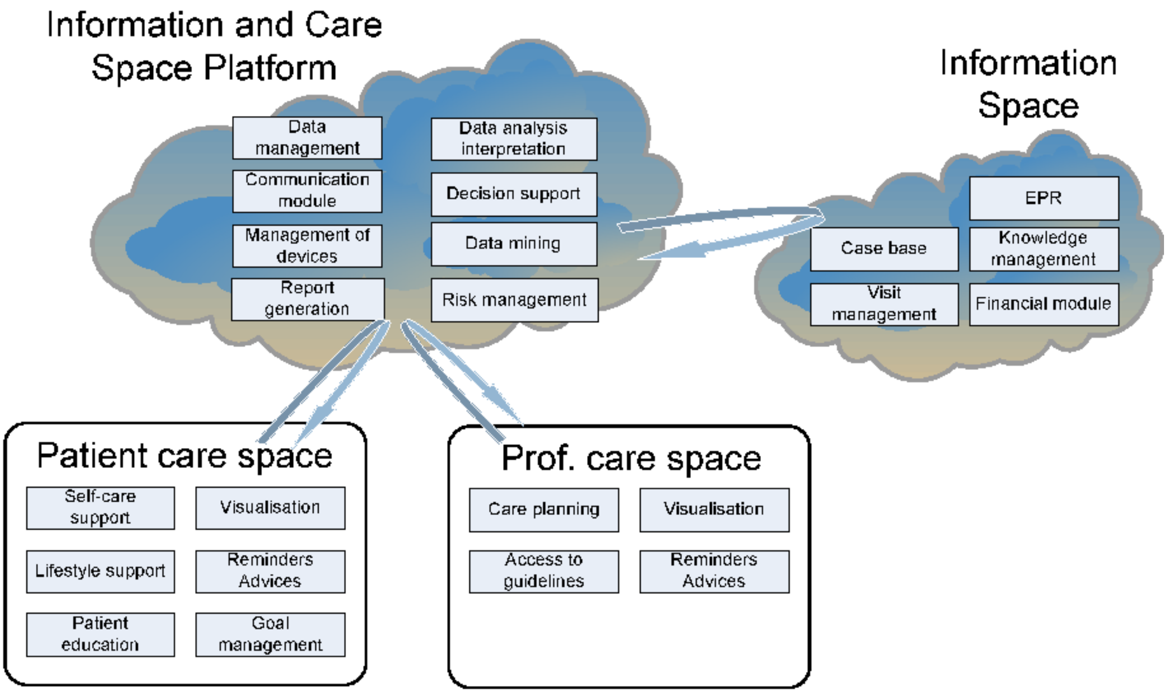

Figure 2.4: The REACTION platform, a cloud-based e-health plan applicable to diabetes personalised care

Source: Thestrup et al. (2011)

Fico et al. (2014) used an ICT platform for a personalised healthcare pathway (PHP) for diabetes disease management. A shift from organisation-centred care to patient-centred care is achieved by the integration of the care system into an ICT system. Varroud-Vial (2011) stated that a follow-up module integrated into an electronic medical record (EMR), electronic reminders, e-health technology and e-mail messaging to patients integrated into the EMR was beneficial to personalised diabetes care. It was also helpful to create and maintain a large database of diabetes containing histories of patient recall, description of care patterns and outcomes, improvement of practices, drug safety, observational research, and retrospective trials.

Significant improvement in accountability was made possible by incorporating all components of a technology-enabled self-management feedback loop to connect diabetes patients with their healthcare team for two-way communication, analysing patient-generated health data and educating patients based on their individual needs and individualised feedback (Greenwood et al., 2017).

There are some works on e-health applications for personalised diabetic care in Saudi Arabia. Alanzi et al. (2014) found that mobile technology and social networking have been accepted by young diabetic patients. The components, requirements, and procedures for Remotely Accessible Health Care at Home (RAHAH) in Saudi Arabia and Pakistan were discussed by Aldahmash et al. (2019). The model also applied to the personal care plan of diabetics. The main barriers to the effectiveness of m-health in diabetics were identified by Alanzi (2018) as shortages in expertise and human resources, funding and infrastructure problems, obstacles related to legal, privacy standardisation and regulatory aspects, and healthcare organisational bureaucracy. The factors affecting the effectiveness of self-care practices for diabetes in Saudi Arabia were identified as culture and religion, gender, stigma, social support, and healthcare environment (Al Somali, 2018). These works indicate that e-health for diabetics has been researched in Saudi Arabia in terms of the use of mobile technology and barriers against its successful implementation. However, the modelling and requirements engineering for these e-health interventions in Saudi Arabia does not seem to have been studied. This research addresses this gap.

The above review demonstrates the possibility of different ways of modelling and requirements engineering for different contexts. However, smartphone-based systems are the most researched and accepted. The following sequence of approaches can be derived from this review for use in the proposed research:

1. An examination and evaluation of the status of the selected e-health system in Saudi Arabia for its effectiveness and efficiency of personalised diabetes care from both quality of care and business performance points of view.

2. Use of manual methods of modelling and analysing the health process, requirements engineering, and the associated health business goals in the context of the e-health system for personalised diabetes care plans.
3. Progress towards an automated method using the results of (2).

WHO (2019) stated that a significant aspect of e-health is the business component and identification of the business values. Therefore, e-health needs to be approached as a business. Current frameworks for e-health development suffer from a lack of fitting infrastructure, the inability to find funding, complications with scalability, and uncertainties regarding effectiveness and sustainability. A business modelling was proposed for solving these problems by van Limburg et al. (2011). The authors argued that the model should involve all stakeholders, engage them in a value-driven dialogue and set goals for technology-led achievements. It should also support the holistic development of e-health technologies. The model proposed by the authors incorporated the latest research on business models, e-health and techniques of persuasion.

The concepts of business organisation, an organisation for change, innovation-led performance, technological competence, stakeholders, health outcomes, and factors and economics enter the business model of e-health. The need for a business model arises from the mismatch between demand and supply. There is also the need to ensure at least a minimum viable level of real-time performance and shifting from post-development to integration into the development process. The business model helps to undertake a value-driven evaluation to select what needs to develop. This will avoid the wastage of resources. The requirements engineering needs to focus on the components of a holistic approach of the Centre for e-health Research and Disease Management (CeHRes) Roadmap reproduced in Figure 2.5.

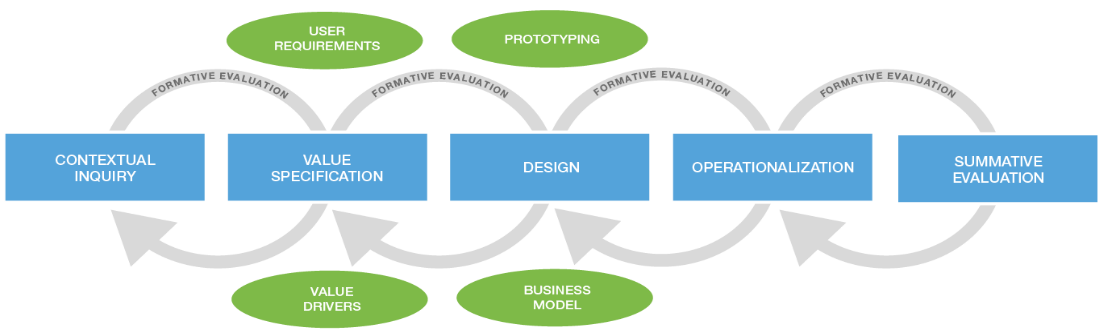

Figure 2.5: CeHRes roadmap for holistic health approach

Source: van Limburg et al. (2011)

In this model, healthcare is conceptualised as a process and the flow diagram follows business processes. Many e-health technologies fail to become sustainable innovations. This failure was attributed to not recognising the interdependencies among technology, the socioeconomic environment, and human characteristics by Van Gemert-Pijnen et al. (2011). The authors suggested a holistic approach to solving this problem, arguing that e-health has shifted from individual care to population care, acute care to disease management and prevention, and from institutional settings to communities and global dimensions through cyberspace. It has also moved from physician-centred to patient-centred participative decision-making. These changing trends call for a multidisciplinary approach. These authors also cited the example of the CeHRes roadmap given above in Figure 2.5. Lex et al. (2013) specified the phases and requirements of the main activities of the road map and suggest methods to meet those requirements. However, their example case of antibiotic stewardship does not cover the requirements in adequate depth.

Interoperability among healthcare systems is an important aspect of e-health models. The organisational, functional, and technical silos of e-health systems are not interoperable in many cases. In the absence of interoperability, it becomes difficult to connect technology to the care continuum. The inherent information complexity of healthcare systems is the basic cause of this asymmetry. For example, one complexity arises from the simultaneous electronic flow of digitalised healthcare information affecting both clinical and administrative processes (Weber-Jahnke et al., 2012). In healthcare, business processes are focused on improving the care of patients and are hence termed healthcare processes (HP). The aim is to reduce cost and improve care quality through the optimisation of the processes. To achieve this aim, support tools or systems are required. In healthcare, support tools are difficult to specify due to differences in perceptions of different people in the system regarding what is required. Sometimes, these are even contradictory.

Adapting international standards may be one way to resolve these issues. In this aspect, García et al. (2015) used a model-driven engineering (MDE) paradigm with the required support systems and compliance with international standards as far as possible. The system was developed for e-health applications of the Andalusian Regional Ministry of Health and Social Welfare and a collaborative case of using this platform with Virgen del Rocío

University Hospital (VRUH) was evaluated. The aims of this modelling were the integration of international standards for the development of Health Professionals and Support Services (HPSS); ensuring that the definition of HP facilitates traceability and effective implementation; easier communication between clinical professionals and IT staff for risk and cost reduction and easier, effective, and efficient maintenance of HP. A five-step methodology was adopted to achieve these aims: HP was modelled based on clinical process metamodel using ISO/IEC TR 24744 standard. For modelling clinical data through constraints and the relationship between them, ISO-EN 13606 and ISO 21090 were used. The standards for concepts associated related with HP and their relationships were set based on ISO/DIS 13940 ContSys. The relationship between clinical process and clinical data, codes for deploying these models in e-health platforms and incorporating specific features to the code for HP platforms was the third step. The archetype metamodel given by the authors is given in Figure 2.6. The supporting tools were also described in the article. The case study was successful in validating the model.

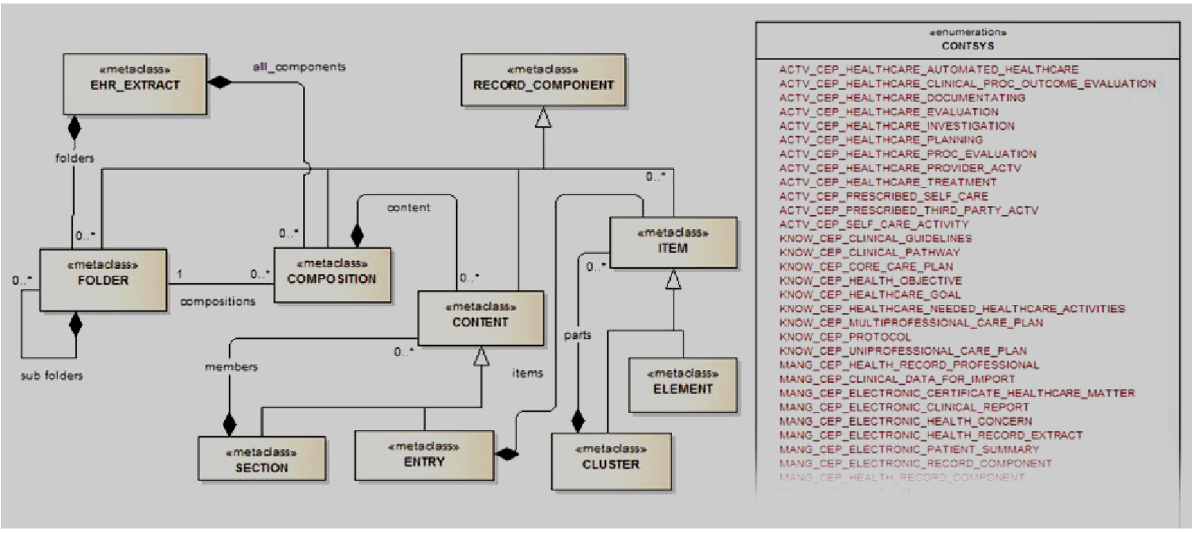

Figure 2.6: Archetype metamodel of e-health system

Source: García et al. (2015)

Van Limburg et al. (2015) used a four-step process for the business modelling of an e-health system for infection management and control. The method involved co-creation with stakeholders as the focus. Stakeholder identification through literature analysis, stakeholder analysis, value co-creation through stakeholder interviews, and process analysis were done and finally integrated into a business model. Alahmadi et al. (2014) proposed an automated e-health business process modelling and address the research gap between systems requirements engineering and e-health goals. The authors did this by explaining the method to derive the business goal-driven requirements in e-health. The diagrammatic presentation of their method is given in Figure 2.7. The routine patient visit process was exemplified to demonstrate the method.

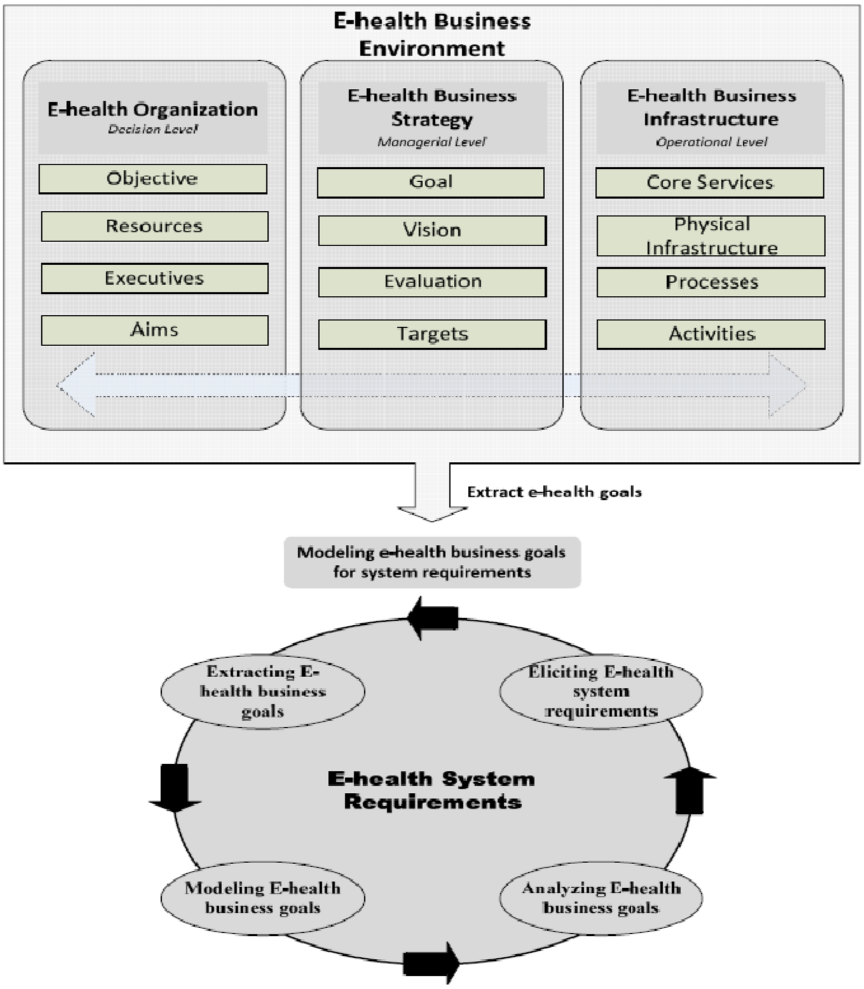

Figure 2.7: Method of deriving e-health goals

Source: Alahmadi et al. (2014)

2.4.4 Requirements Engineering and Modelling in E-health.

Adenuga et al. (2015) identified integration and interoperability issues as the major problems causing the failure of e-health efforts. The authors presented an adaptable e-health model in which requirements were described based on healthcare needs, system, implementer, and hardware. To solve the interoperability problem, Kuziemsky and Weber-Jahnke (2009) proposed an e-business-based framework in which specific processes and tools and applications to the multiple levels of the healthcare system are used. In the context of the increasing complexity of healthcare processes due to the wider adoption of e-health systems, interoperability has become a serious issue. Within the standards of interoperability, e-health providers are building application-specific interoperability profiles as per the standards relevant to these applications only. Bourquard et al. (2015) proposed an approach based on these profiles to ensure adequate interoperability.

The co-construction of services and technology was identified as a method to prevent the failure of healthcare IT projects by Hyppönen (2007). The author suggested that e-health project participants need to better understand development as the parallel implementation of multiple objects. Therefore, better skills in managing the change process and a better understanding of collaboration methods through networking throughout the development were required. The author applied these concepts to one case study and validated its findings with another case study. In many e-health projects, there is no complete understanding of the needs of end-users. The importance of identifying end-users correctly and completely was stressed by Kayser et al. (2015). The authors proposed a user-task-context framework to tackle this problem.

The processes of developing a requirement engineering framework were described by Tara (2007). The existing methods of requirements engineering were reviewed and a framework for knowledge requirements engineering was developed in the first step. The second step consisted of an evaluation of the usability and usefulness of the proposed framework using a four-phase study. During these phases, the types of information to be included in a quality healthcare website were derived from knowledge requirements engineering. Requirements data as per this established framework was gathered from various sources. The results of the evaluation revealed that the pieces of information and health topics specified using the framework were almost always the same as those preferred by the users. Also, evidence obtained on such information helped the subjects choose the resources that matched their interest when they were used by health search engines to index and retrieve online health resources. The data showed a higher satisfaction of the subjects with the health website built based on the knowledge requirements specified as compared to the other selected health websites. The author presented a diagram of the e-health taxonomy of branches as presented in Figure 2.8. This taxonomic structure provides the complete picture of the entire system and its components required for e-health modelling and requirements engineering.

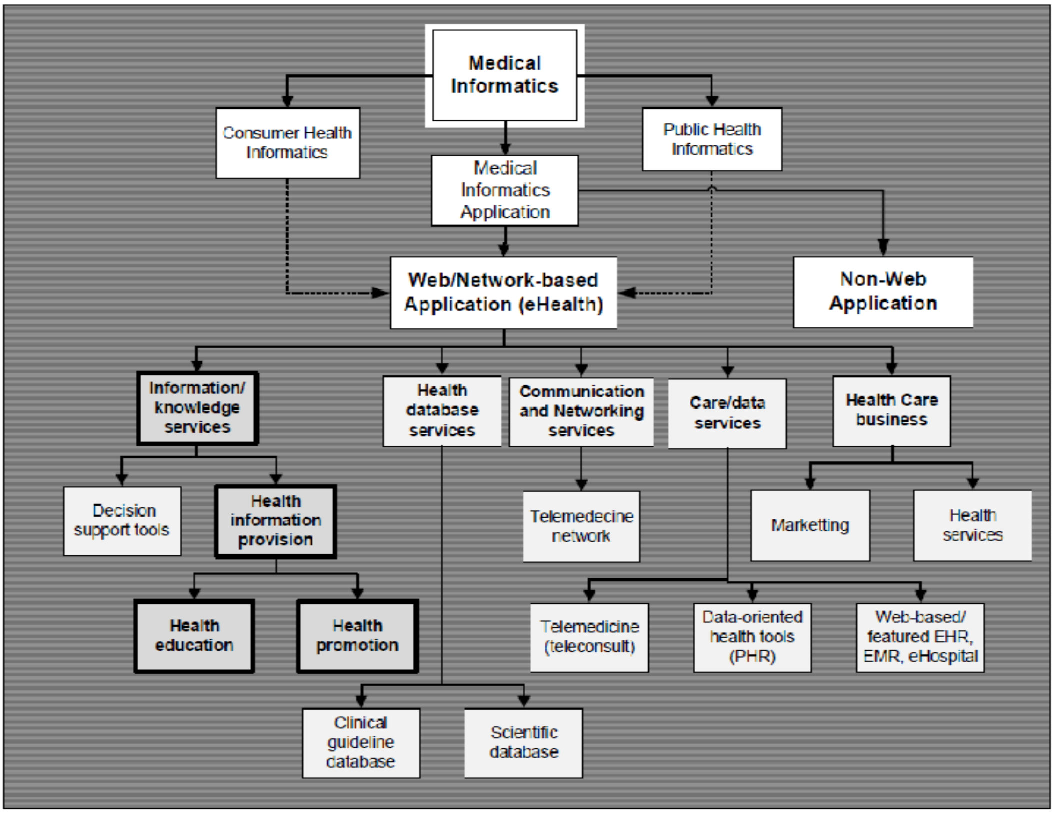

Figure 2.8: Taxonomy of e-health applications

Source: Tara (2007)

Another knowledge-intensive e-health applications requirements engineering was diagrammatically presented by the same author as in Figure 2.9. This ontological representation is comprehensive enough to start designing the system.

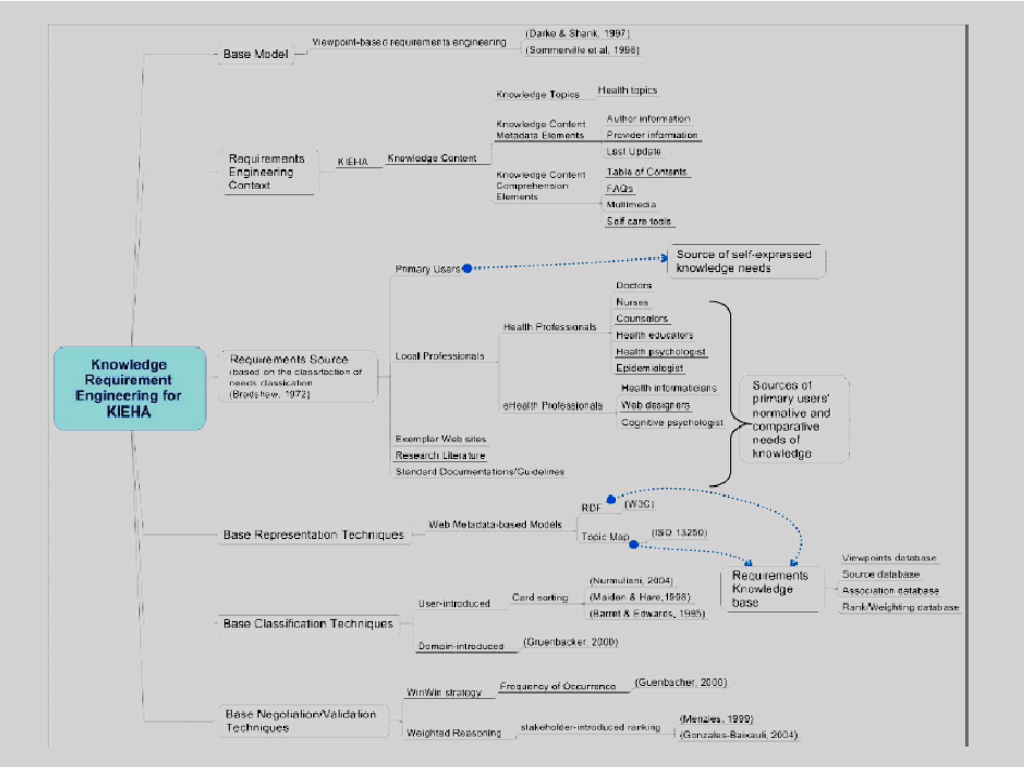

Figure 2.9: Taxonomy of e-health applications

Source: Tara (2007)

The possibility of socio-technical problems due to non-clarity in the use of data as a commodity was explored by Ure et al. (2009) by examining several e-health grid projects in which infrastructure for data reuse and sharing had been provided and their strategies to solve this problem. The need to adapt strategies depending on the context was evident from these evaluations. The need for knowledge engineering to close the research–healthcare gap was highlighted by Beck et al. (2012). It requires engineering the bidirectional flow of data. Thus, processing research data and knowledge to identify clinically relevant advances and delivering these to healthcare use becomes one direction of knowledge flow from theory to application. The other direction of knowledge flow is in the reverse direction by making available those outcomes from the application of knowledge back to research. This system can self-optimise when both knowledge-flows balance each other.

A significant problem of e-health systems is their long-term fault-free maintenance. Failures are possible due to several reasons. These faults and failures affect ensuring business resilience. In this context, Rejeb, Bastide, Lamine, Marmier, and Pingaud (2012) proposed an approach based on a business continuity management (BCM) framework to ensure the required business resilience. They developed a business continuity plan based on model-driven engineering.

Run-time management of self-adaptive systems is an important issue due to the uncertainty of the environment. Also, new needs for users may arise, even while using the system. This could be due to environmental variations. This necessitates runtime to evolve according to variations of the user and the context in the self-adaptive systems. This is particularly applicable in the case of e-health. To address this issue, Inverardi and Mori (2011) incorporated a notion of contextual correctness within the runtime dimensions and design a generic system. To address the diverse needs of different types of e-health network users, Vasilyeva et al. (2005) proposed an adaptive user interface based on the ideas obtained from a review of the current research status on the topic.

Cloud computing enhances the features and functionality of e-health systems. However, when patients' health records are moved to a cloud computing regime, privacy and security of information become critical issues in e-health systems. The requirements for the protection of privacy and security of information in this context were examined by Rodrigues et al. (2013) The solutions offered were role-based access, enhancing the security mechanisms of the network, suitable types of data encryption, incorporating digital signatures and methods to monitor access and compliance with the various standards and certification requirements by cloud service providers. There was also scope to use blockchain technology for this purpose.

Fitterer and Rohner (2010) applied effective design requirements to the construction of a networkability maturity model for healthcare providers, which could be used in e-health contexts. Their model is useful in assessing the capacity of an organisation for efficient engagement in business relationships. Thus, it becomes an e-health business model. A framework for human support for adherence to e-health interventions through supportive accountability was developed from the literature available on psychology, motivation theory and communication research. Patient motivation influences the extent of human support required. The more the patient is motivated, the less support is required. Communication media also have some influence on the effect of human support (Mohr et al., 2011).

Mobile e-health or m-health has much potential with the increasing use of smartphones, wearables, mobile augmented reality/virtual reality (AR/VR), smart houses and smart care sensing and interaction facilities all over the world. The early promises of these technologies have suffered due to certain challenges. Some of these challenges listed by Grundy et al. (2018) were efforts required to develop, deploy and maintain them, a low level of end-user acceptance, difficulty in integration with other health systems, difficulty of catering to diverse types of users, inadequate feedback to developers, lower level of sustainable adoption, and even lack of success.

Nauta et al. (2015) applied the e-health innovation Matrix (eHix) framework for the development of e-health applications. The authors explained the eHix in detail and evaluated the scope of its application in multiple ways. An application system for the current context was then presented. The eHix presented by the authors is shown in Figure 2.10. There are 20 cells in the eHix framework with the implementation process horizontally and components in a vertically placed format.

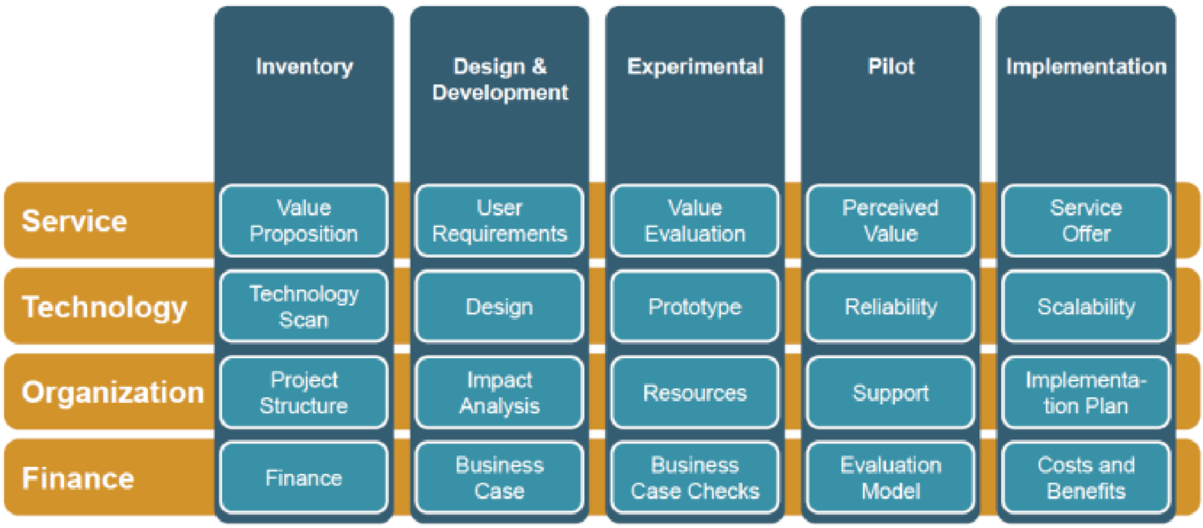

Figure 2.10: The eHix Framework

Source: Nauta et al. (2015)

Gerhardt et al. (2017) offered action research as a solution to address the unsustainable nature of m-health in general in a review. Both qualitative and quantitative research were reviewed. However, there is a general scarcity of using action research in e-health contexts. Requirements engineering for data analytics of e-health were considered by Liu et al. (2016). They argued that the questions to be answered were:

a) What should be identified as the relevant problems when data analytics technology is the solution?
b) How to deal with the accumulated data?

c) As the collection, storage, retrieval and processing of data do have costs, what standards should be applied for making decisions on big data treatment and their analytics?
d) What are the purposes and the methods of data collection for these purposes and how should these be determined?
e) What type of data management infrastructure is to be used for supporting the usage of the collected data?
f) What are the analytical functions needed to achieve the intended aims?
g) Is it better to treat data on a case-by-case basis or use a common standard procedure for all the data?

Healthcare organisations need to consider all the above questions to come up with a good data analytics system for their health information data. Many approaches and applications are discussed by the authors before a desirable one is suggested. The national-level implementation of an integrated holistic e-health model in Kuwait was considered by Al-Sharhan and Omran (2019). All success factors for efficient e-health services delivery under a new security model to access healthcare records were incorporated. The principles and methods of evaluating usability and safety, the two key aspects of e-health systems, were discussed by Price et al. (2016). Questions like when and how to evaluate were considered in relation to both aspects. The need for frequent usability and safety checks to prevent medication errors was particularly stressed using examples.

One of the main issues in designing digital healthcare software solutions is ensuring that these solutions address the clinical needs and requirements of key services and the expectations of various healthcare professionals. Therefore, software requirements engineering must cater for this demand. Traditional methods of determining requirements engineering processes are weak in the elicitation and validation of key requirements when multidisciplinary teams of health professionals interact. Using an iterative process and inputs from several stakeholders with overstretched and fragmented services, Tryfona et al. (2017) proposed new methods of software requirements engineering for an e-health system on diagnosis and support of autism spectrum disorders (ASD) in young children in the United Kingdom (UK) by the National Health Service (NHS).

The information integration requirements for e-health in traditional medicine were discussed by Ikram et al. (2018). The authors conducted a literature review on both traditional and modern systems to determine the most suitable health information system model with the integration technologies and standards required. The integration of data, interoperability, information model, workflows and access to various repositories from different platforms were identified from the review. Databases for medication and procedures were required for traditional medicine systems with facilities for new data integration.

In another systematic review from Panama, two e-health platforms were presented by Barrios et al. (2018) as examples of the migration of health systems from client-server architecture to web-based and ubiquitous paradigms. Both platforms were modelled, designed, developed, and implemented successfully. In the first platform, using ambient-assisted living and ubiquitous computing, palliative care provided to elderly patients and those with a terminal illness were enhanced. This made the work of doctors, nurses, and other health actors easier. In the second platform, machine-learning methods and a data-centred ubiquitous repository of patient results were applied to improve the Down's syndrome risk estimation process for accurate predictions based on the parameters used for local woman patients. Both methods improved the physical and psychological wellbeing and quality of life of all patients and their families.

An original tooled fully automated risk-driven security testing process, pattern-driven and model-based vulnerability testing was reported by Vernotte et al. (2015). The authors' aim was to improve the capabilities to detect various web application vulnerabilities, especially those related to SQL injections, cross-site scripting and cross-site request forgery. The system was validated on a freely accessible complex e-health system developed by Info World.

ArchiMate is an enterprise architecture modelling language for business applications and technological architecture. Yamamoto et al. (2018) used this software to design a business model for e-health in Japan. The Actor Service Object Means Goal (ASMOG) paradigm was used in the designing of the model. A picture archiving and communication system (PACS) business model using ArchiMate was given by the authors.

Firouzi et al. (2018) noted that advances in medical and technology fields have created new opportunities for precision e-health and m-health services for personalised healthcare. The Internet of Things (IoT) brought a paradigm shift in the healthcare horizon, as it provides several advantages like availability and accessibility, the ability to personalise and tailor content and cost-effective delivery in healthcare services. However, there are still many challenges to the development of consistent, suitable, safe, flexible and power-efficient systems for medical requirements. Only the coming together of significant technological advancements in the hardware and software communities can bring the desired changes in a reasonable time.

Brost and Hoffmann (2015) outlined in detail a four-step approach to get a reliable and robust e-health system architecture and specifications. The following steps are listed by the authors:

1. Decomposition of the system to identify the assets based on the multilateral security concept. This means all participants of an e-health scenario are treated as potential attackers.
2. Holistic and systematic modelling of threats through the evaluation of threats based on Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service (DoS), and Elevation of Privilege (STRIDE).
3. Defining and using case-specific security requirements and privacy concerns along with their relevance.
4. Mitigation of threats by determining the countermeasures to be implemented.

A model-based jobs theory (MBJT) capable of visually modelling the jobs theory of Christensen is proposed by Yamamoto et al. (2018). The applicability of MBJT was also tested by designing an e-healthcare service. According to Christensen's jobs theory, the question is, "What job would consumers want a product to do for hiring it?" In terms of the jobs theory, this means, "When we buy a product, we essentially 'hire' something to get a job done. If it does the job well, when we are confronted with the same job, we hire that same product again. And if the product does a crummy job, we 'fire' it and look around for something else and hire to solve the problem" (Gerdeman, 2016). Privacy engineering requirements in m-health applications need to be based on the pseudonymity of patients, data minimisation and transparency for patients. This conclusion was arrived at by Gabel et al. (2017) based on their studies on m-health applications in goal management training. In this context, the authors used neuropsychological training for cognitive rehabilitation when executive dysfunction occurs in the brain due to a brain injury.

Descamps et al. (2016) described a methodology for the engineering of smart environments in which a multi-agent system is used. The method is an extension of an existing multi-agent system (MAS), and agent-oriented software process for engineering complex systems (ASPECS) approach. This approach allows situational engineering principles. The most important elements of this methodology are identifying the hierarchy of goals, the description of detailed requirements and the relationship of each goal with sensors or effectors, the description of different levels of ontologies, the problem conceptualisation, and all involved experts. The rest of the methodology consists of refining the model to enable the identification and description of agents of organisational structures and behaviours. The methodology is tested on an e-health platform, which monitors patients who have experienced heart failure.

To assist in web-based intervention programs for behavioural and psychological interventions, Reblin et al. (2017) designed and developed the electronic Social Network Assessment Program (eSNAP) based on the (CeHRes) roadmap. The application was aimed at supporting family caregivers attending neuro-oncology patients. Five iterative stages were used: contextual inquiry, value specification, design, operationalisation, and summative evaluation. These steps were preceded by research activities consisting of a literature review, focus groups and iterative rounds of interviews. Some lessons were learned during the design and development of the eSNAP system. These were how to translate theoretical needs and ideas to real-world problems, how to prioritise needs to be addressed at each step and time, how design requirements change with delivery modalities, and how to develop a fit tool for the specific context of use.

In 2016, there were over 97,000 e-health apps available in all the app stores put together (Heffernan, et al., 2016). However, they varied greatly in their effectiveness. A small number of these apps were developed using a good theoretical basis and in consultation with healthcare experts; however, the remaining large majority were not developed similarly. Concern exists about whether these may cause harm to the users of the app. In the absence of any unified formal theory for developing interactive e-health apps, it is difficult to develop systems and applications for complex messaging in health promotion and prevention. Realising these problems, Heffernan, et al. (2016) used a case study of complex messaging for the Safe-D project. The complex messaging guides people for a safe but sufficient ultraviolet (UV) exposure for vitamin D synthesis in the body of users. Apple and Android apps, both named Safe-D, were developed to safely improve vitamin D status in young women by encouraging them to engage in safe UV exposure. For this purpose, participatory action research was used. The participants consisted of medical researchers, human–computer interaction researchers, clinicians who were experts on the subject, external developers, and target users. Based on the results, recommendations for Safe-D and generalised recommendations and guidelines were proposed for developing interactive e-health applications for complex messaging aimed at health promotion.

Workplace health promotion (WHP) can be done through e-health and m-health applications. There are several challenges in integrating these applications for workplace health promotion activities. Some of the current tools can be used for the whole WHP process or in parts like group administration, information flow, assessment and intervention development process and its evaluation, depending on the requirement. Jimenez and Bregenzer (2018) developed a life cycle model of WHP based on the WHO model of the continual improvement process for a healthy workplace. The WHO model can be adapted to specific contexts. The process contains seven steps, all of which promote workplace health. The specific successes were in terms of easier administration, providing a platform for information and communication, supporting assessments, presenting, and discussing assessment results in a dashboard and offering interventions to change individual health behaviour. The important success factors were automatic feedback about health parameters, the creation of incentive systems and bringing together of a large number of health experts in one place. Careful strategies need to be devised for data security, anonymity or lack of management involvement. Specific steps to prevent nonparticipation and dropouts may also be required.

2.5 Readiness of the Saudi Arabian Healthcare Systems for Diabetes: A Systematic Review

2.5.1 Introduction

Numerous reports find a significant proportion of population of Saudi Arabia is affected by diabetes (Al Slamah et al., 2020; Robert et al., 2021). According to the data in Statista (Statista, 2023), the total healthcare expenditure on healthcare in Saudi Arabia was 49.1 billion USD against a budget of 44.5 billion USD (167 SAR) (KPMG, 2019) in 2020. This is expected to increase to 77.1 billion USD in 2027. In 2020, the Ministry of Health of Saudi Arabia spent a large amount of approximately US $6 billion on diabetic patients and their treatment. This amount was almost 16 percent of the annual budget of Saudi Arabia (Al Slamah et al., 2020). Some countries have their own self-management programs for diabetes. These self-management programs encourage patients to take control of their health and be able to handle their medications and diabetes prevention on their own. Saudi Arabia lags in relation to its development of self-management programs for diabetes.

Although diabetes is a chronic disease, with proper management and treatment it can be controlled and managed well. Educating diabetic patients about diabetes and training them about self-management is vital in combating the disease in the long run. It is important that diabetic patients have complete knowledge and understanding of the disease, its complications and risk associated with it. Over the last one decade, the prevalence diabetes has grown rapidly in the cities of Saudi Arabia. It is believed to have affected around 20 percent of the adult population, and by the next decade, its incidence is predicted increase further (Robert et al., 2021). This section provides information on the current situation of diabetes in Saudi Arabia and attempts on increasing the capacity of the healthcare systems.

The objective of this literature survey is to draw such articles that provided information regarding the current situation of diabetes in the kingdom and the attempts made to increase the capacity of the healthcare systems.

Despite the attempts of governments to introduce self-care/self-management, there is negligible similar work being done in Saudi Arabia in comparison to the developed nations. Robert et al. (2021) conducted a thorough review of the literature available on the current scenario and awareness among people of Saudi regarding diabetes. They found that diabetes is a threat to the economy and the demography of the Saudi state that will increase in the long run if current trends persist. Abdulaziz Al Dawish et al. (2016) stated that in 2016 Saudi Arabia was the seventh most diabetic affected country worldwide with a total of 40 percent of the total population has been affected by diabetes. This might have its roots in the fact that Saudi Arabia is one of the largest consumers of sugar, red meat, and carbohydrates. The easy availability of these foods makes the Saudi Arabians prone to diseases like diabetes (Wang et al., 2010). These revelations provide further information about the high prevalence of diabetes in Saudi Arabia.

Diabetes is a genetically affected disease that can be controlled using self-management techniques. Obesity, poor food choices, excessive smoking and low or no physical activity are some possible causes of diabetes (Altall et al., 2019). To curb the complications of diabetes, patients need to practice diet control, exercise and monitor their glucose levels regularly. This cannot be done unless the patient is well versed with the monitoring devices used and educated about the disease itself. For example, understanding that regular exercise would increase the quality of life of diabetic patients. Diabetic patients may struggle to identify a suitable diet and with correct serving sizes of food. Also, there is a dearth of literature regarding dietary knowledge and self-management techniques (Sami et al., 2020). Although a proper diet plays an important role in managing diabetes, the diabetic patients of KSA had no or very little knowledge regarding which food contains what minerals and what should be the proper intake of those foods (Sami et al., 2020). The Centre for Disease Control and Prevention had declared self-management and diet control as a vital step in checking a patient's information related to diet and nutritional aspects, the complications related to it and the treatment. (Sami et al., 2020). Proper knowledge of foods and nutrients is important for diabetic care overall (Backman et al., 2002). Despite the importance of the self-management practices mentioned here, several studies revealed that patients did not follow them closely (Alali et al., 2019). For example, Alali et al. (2019) found that except for medication, no self-management practices were followed by [the diabetic patients]. The authors suggested that since Saudi Arabia is an Islamic state, cultural interventions could help to make its diabetic patients follow self-management (Alali et al., 2019). Some studies even revealed how only a small number of patients knew the importance of a good diet to deal with diabetes and that the patients did not follow the diet that was recommended to them by physicians (Sami et al., 2020; Backman et al., 2002). Also, paying low regard to exercise and medication resulted in high occurrences of chronic diseases. However, treatment for diabetes demands both a transformation in lifestyle as well as an abstract pharmacologic treatment schedule. This can be achieved through effective awareness and knowledge development combined with behavioural change. The motive of educating diabetic patients about diabetes and its management is to help them to understand the graveness of the disease and its impact on their health. Then, patients can have a treatment that are customised for them as per their personal requirements. One widely used method for imparting self-management education for diabetes is the gamification approach that motivates the users towards the given activity involving the use of technology (AlMarshedi et al., 2014). It has garnered special attention for being the optimal solution in initiating the active participation of patients in the elf-management of diabetes. However, little research has been done concerning the usability of gamification and the readiness of patients towards the gamification approach. The following section describes the methodology adopted for a systematic review on diabetes self-management in Saudi Arabia. This review is aimed to provide readiness assessment and insight into the key factors which need improvement and help in the smooth and timely implementation of Saudi Arabia's Vision 2030 to achieve its healthcare goals.

2.5.2 Methodology

The methodology used for this study was a systematic literature review. The first step was to look up research conducted on diabetes in Saudi Arabia and surrounding countries. This includes reports on the management, treatment capacity and self-management of diabetes. Studies reporting efforts taken in the past to increase this capacity were also sought. Studies based on both types of diabetes, Type 1 and Type 2, were involved and diabetes in children and people of all age groups from both genders were included. The review took place between September and October 2021.

1. *Eligibility Criteria*

Articles that were published in English between 2014 to 2021 and some with only the abstract written in Arabic were considered. The studies that had relevance to countries and cities of Saudi Arabia were selected. Studies that talked about readiness and self-management against diabetes were given preference.

2. *Information Sources*

The databases that were selected for the purpose of those studies were Elsevier, MDBI and Google Scholar. Those were chosen based on their comprehensiveness and relevance to the topic. Journals that have a good coverage of the topic were accessed and searched thoroughly to make sure no relevant paper was omitted. The selected articles underwent a regressive sorting using several criteria to arrive at the most relevant papers. Some grey literature sources were also taken into consideration.

3. *Search Strategy*

To select the relevant papers, keywords like, "diabetes," "Saudi," "readiness," "self-management," "healthcare," "healthcare workers," "cost effective treatment," "capacity of healthcare," "management of diabetes," "detection and diagnosis," "adherence to medicine," with the year of the research sought were search. Most of these keywords drew papers relevant to this research. Irrelevant and duplicate articles were excluded, as were reports, anonymous studies or case studies.

4. Study Selection

I identified all papers that were in the English language and that contained the following inclusion criteria: city based, readiness for the management of diabetes; empowerment of patients for self-management of diabetes; efforts of the healthcare workers; capacity of the medical staff from physicians to nurse; and efforts to scale up this capacity. To start with the review, the initial selection of studies was screened and narrowed to remove duplicates and the studies that were not relevant to the main topic. The remaining articles were then screened on the inclusion criteria basis.

5. Data Collection

After a thorough study of all those articles that were relevant and met the eligibility criteria, notes were made. These notes had information regarding year of study, objective of the study, methodology, outcome of the study, publication, future work and the work done so far, existence of schemes and policies for diabetic patients, diagnostic capacity of the healthcare system, availability of physicians and paramedical staff, doctor to patient ratio, management of the diabetes medical record, level of self-management of diabetes among patients, and steps that can be taken to improve the condition of the overall healthcare system.

2.5.3 Results

A total of 170 papers were initially selected. After title and abstract screening, these 170 articles were narrowed down to 69. Some articles were excluded based on region, location and language, thereby further narrowing down the list of papers to 35 for full text review, as depicted in Figure 2.11. These 35 articles met the eligibility criteria. The total number of references after full text-based selection was reduced to 21. Then these articles were subject to a final quantitative analysis. Mixed results regarding the readiness of Saudi healthcare were derived from these papers. A total of seven areas that talked about diabetes, its current situation in the kingdom and what could be done to improve it were derived from the analysis. The seven studied areas are the capacity to diagnose diabetes, the capacity of healthcare workers, total strength of the healthcare system in the country, pilot experience for increasing patient adherence to treatment, the existence of electronic medical records, national guidelines for diabetes care, and integration of diabetes care into the existing healthcare system.

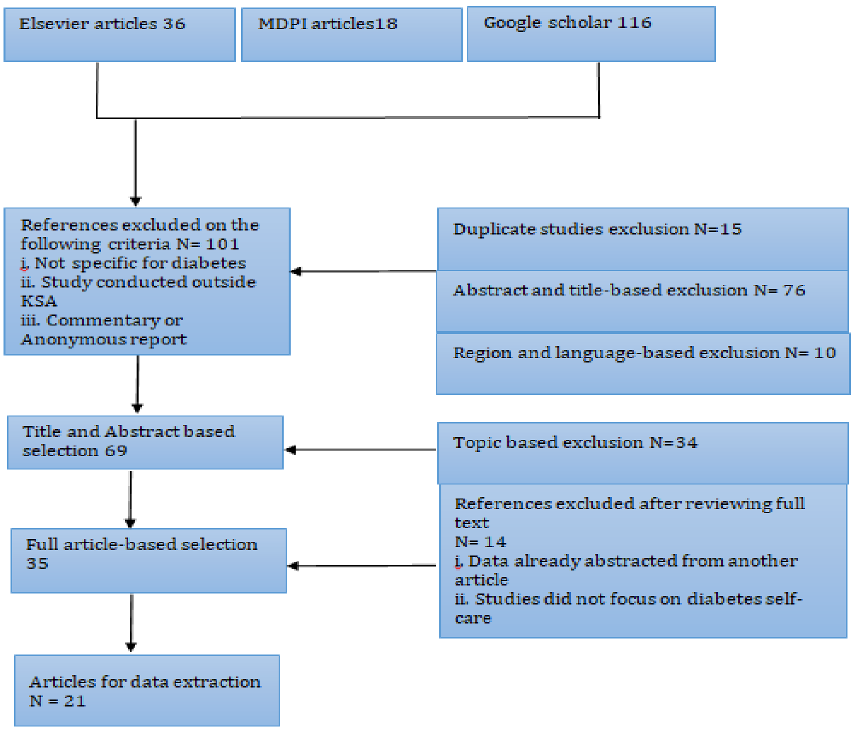

Figure 2.11: Search and study selection

The main areas upon which the study remained focused are discussed in the following sections.

The Capacity to Diagnose Diabetes

The most important role that any healthcare system of a country should play is the timely detection of diseases. Similarly, the Saudi Arabian healthcare system must be active in the detection of chronic diseases like diabetes. The Saudi healthcare system has several national schemes and types of insurance that citizens can use free of cost, such as for the early detection and diagnosis of diabetes. Saudi Arabia is making efforts to develop its healthcare system by making diagnosis and treatment affordable. However, that will not be sufficient in dealing with a disease like diabetes. Due to the high prevalence of diabetes, it is impossible for healthcare professionals to address every patient, thus self-care management programs are essential. Certain healthcare focus groups keep accounts of the available resources and their impact on the patients' care and professional services. This included information about infrastructure, staff and apparatus. These groups aimed to enable these resources to be more available and attainable for the patients. Due to a lack of healthcare professionals and a rise in diabetic patients, staff may be left in a bad situation because of the limited time to attend to a patient and also educate them about self-management, especially newly diagnosed ones. Educating patients can be done through different means, such as a one-to-one consultation tailored particularly for the patient. Patients' compliance with medication and self-management methods leads to the patient's taking responsibility for their own health in accordance with cultural and social attitudes (Al-Hanawi et al., 2018). The big cities in Saudi Arabia, such as Riyadh, Buraydah and Jeddah, tend to have better infrastructure, facilities with technically sound equipment, and specialised workforce and hospitals. The hospitals in these big cities provide high levels of healthcare, including advanced operations and diagnostic centres. However, small healthcare units like the primary healthcare centres are spread across villages and small towns largely lack such facilities (MOH, 2015). The total number of primary healthcare professionals in Saudi Arabia for 2010 to 2014 is given in Figure 2.12 (MOH, 2015). No substantial change in healthcare workforce happened during this period affecting the healthcare capacity of the country. Saudi Arabian healthcare does not have many well-developed programs for the self-management of diabetes. However, some studies revealed that few programs that were originally made for Type 2 diabetes proved to be beneficial in controlling glycemia in patients. These programs helped patients in adopting a healthy lifestyle, like doing exercise daily, engaging in more physical activity and eating a proper diet. However, it is important to mention that such self-management programs would not be successful unless they were culturally and socially suitable to the environment and to its people. Few studies have taken into consideration the cultural aspect of Saudi Arabia and its influence on the treatment of diabetes (Al Slamah et al., 2017).

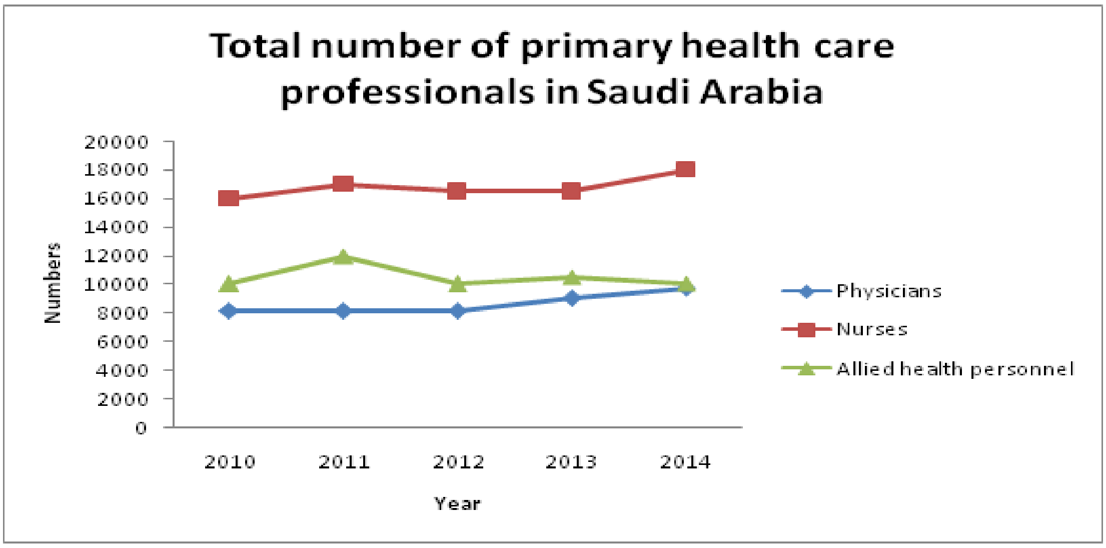

Figure 2.12: Graph showing total number of primary health care professionals in Saudi Arabia (MOH, 2015).

Capacity of Healthcare Workers

Due to the unavailability of medical staff, the capacity, and the quality with which a professional should work is reduced to a low level. The capacity and efficiency of the workers is compromised because of the disproportionate ratio of medical staff to patients (Asmri et al., 2020). Doctors and nurses need to take care of many patients at once, which affects healthcare directly and indirectly. Shortage of doctors (see Figure 2.13) and nurses affects the time spent with each patient and thus the care quality. ~~at a time.~~ It is important that each patient gets enough and appropriate time. Each patient's needs and queries should be addressed. Moreover, it is necessary to spend enough time with each patient to explain about nutrition, its functions and how it is related to diabetes as well as how sugar levels in the body can be adjusted with proper nutrition and how high blood sugar is related to weight gain (Asmri et al., 2020). It would be difficult for doctors and nurses to have time to cover all the of the necessary topics if there is an increase in the number of patients, so it might be necessary to have recurring appointments for patients for full treatment. It was considered that there were fewer healthcare workers that required to treat the number of patients visiting per day. So, it was not possible to educate every patient individually and properly about diabetes and its management. Increasing the number of working staff could help to address this issue. It was noted that patients could not receive high-quality and full diabetes education due to increase in the number of such patients and long waiting times for appointments. So, increasing staff at a particular centre and increasing the number of such centres in an area would help to solve the issues related to educating people regarding Type 2 diabetes (Asmri et al., 2020).

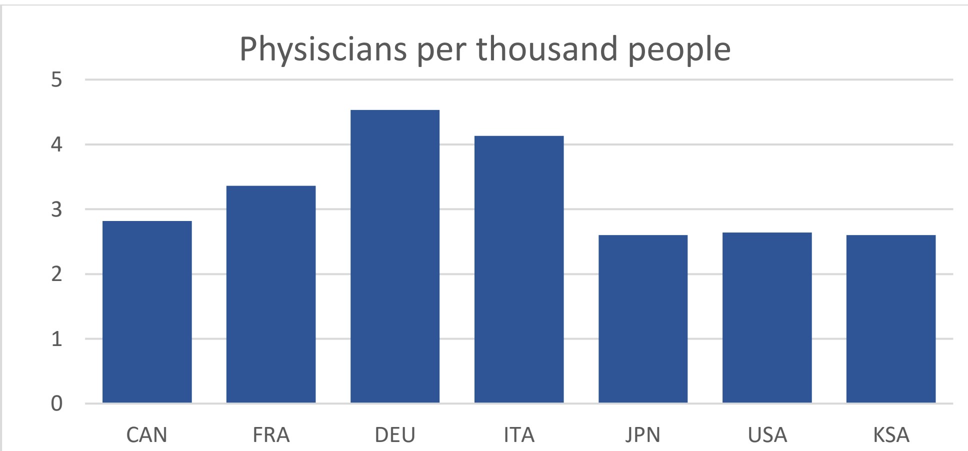

Figure 2.13: Graph showing practicing physicians per 1,000 population in various countries (MOH, 2015)

Total Strength of the Healthcare System in Saudi Arabia

Shortages in the numbers of healthcare professionals is a matter of concern around the globe. The healthcare system of Saudi Arabia is no different. Most of the doctors and nurses working are non-locals (MOH, 2015). Despite having many healthcare professionals from other countries and local healthcare workers, the country falls short of medical staff. This low number of total staff available has affected the efficiency of individual workers. Often there is only one nurse or doctor is available for hundreds of patients, rendering the healthcare system ineffective and almost useless. According to a survey conducted in 2014, the primary healthcare staff counted 9,304 physicians and 18,136 nurses, with a ratio of three physicians and almost six nurses per 10,000 persons, which is a poor doctor-to-patient ratio as depicted in Figure 2.12 (MOH, 2015). Due to unmanageable workload, many healthcare workers, particularly nurses, are switching departments preferably to non-nursing departments, which worsens the worker shortage and increases demand even further. This is not the case with paramedic staff only. However, the physicians and other specialists are also lower in number than required. A survey by a ministerial committee revealed that there were 40 percent fewer physicians in primary healthcare than needed. The total number of physicians in Saudi Arabia is very low in comparison with a few other countries, as shown in Figure 2.13 (MOH, 2015). Among this low number, many occupy top positions of management and leadership within the healthcare department, which adds to the scarcity of practicing physicians (Asmri et al., 2020).

Pilot Experience for Increasing Patient Adherence to Treatment

Patients not adhering to proper medication and not eating a good diet result in poor impact of medication prescribed and uncontrolled glycemia, resulting in worsening the condition of diabetic patients' health and lifestyle and an increase in death rate. Chronic diseases like diabetes require long-term medication and treatment. Taking proper medication is necessary to combat the disease. Long-term adherence is explained by WHO (WHO, 2003) as the process of sticking to treatment for as long as it becomes a habit and impacts the lifestyle in a progressive way. A survey by WHO reports that the medication adherence in developed countries is 50 percent and it is lower in developing ones. In case of Saudi healthcare, a much higher medical adherence is required given to the high percentage of diabetic patients in the country. Along with negligible adherence to medicine, the report also showed patients followed poor lifestyle habits. This leads to the worst scenarios of the diseases and an even higher mortality rate, thereby deteriorating the financial condition of the patient and as well as the economy of the country at large.

Many surveys have been conducted to document the medication adherence of diabetic patients towards prescribed medicine. A cross-sectional study was conducted among a group of Saudi patients with diabetes. The survey was carried out in clinics in King Fahd University Hospital, which is the tertiary healthcare facility around the region of Khobar. The survey was conducted using valid questionnaires prepared for the same purpose. The questionnaires were translated to the local language from English to cater to the local population (AlQarni et al., 2019). The questionnaires were developed to assess patients' knowledge, attitude and practice regarding diabetes, the risk associated with it and its management. The questionnaire had six sections ranging from demographic questions to the lifestyle of the patients. The first section asked questions related to demography of the patients, while the second evaluated their knowledge regarding diabetes. The third and the fourth sections asked questions regarding the practices the patients followed then a section on diabetes management and important lifestyle choices. The last section had questions about the attitude of the patient towards space, including patients who were current being treated for diabetes and those who been treated previously and were on oral medication only (Alqarni et al., 2019).

A similar study was conducted on a population of 375 people, who had either Type 1 or Type 2 diabetes, and were undergoing treatment under the Bisha Governorate (Alqarni et al., 2019). The patients selected were above 18 years of age and had been involved with medication for 3 months. Pregnant women and patients with an intellectual disability were excluded from the sample. The level of adherence was measured by making use of the four-item Morisky Green Levine Medication Adherence Scale (MGLS). Participants were asked to fill out questionnaires that had questions related to medication and their socio-demographic information. Questions such as if the patients took their medicine on time, if they usually forgot to take their medicine, if they stopped taking medicines when they feel a little better or increased their intake when they feel sicker were asked. The scores on this MGLS scale were set from 0 to 4. Each number was either a yes or a no. For every positive response a point was scored, with lower scores implying better adherence. An analysis was conducted afterwards using SPSS version 22. Assessment was conducted on the patients recalled report after undergoing medication for at least two weeks. The adherence levels of those patients were found to be below par and insignificant. Both surveys point towards the need for a better management of the disease, and an individual approach to the patients by the primary healthcare workers and identifying patients' adherence levels to medicine for a successful treatment (Alqarni et al., 2019).

Existence of Electronic Medical Records

The healthcare system in Saudi Arabia witnessed a dynamic shift after switching from the conventional paper-based medical records to electronically recorded digital versions. EMRs (electronic medical records) have been helpful throughout the healthcare system, particularly in storing large amounts of data related to patients' medication and treatment history. Patient records are needed to determine the precision and reliability of the healthcare services provided. The older method of recording that was being followed for years was convenient but error prone. Any number of errors could occur, like missing data, incomprehensible writing, the inability of simultaneous data retrieval and unavailability of large storage units for storing medical data files (AlMarshedi et al., 2014).

The transition from conventional PMRs (paper medical records) to EMRs has improved services. EMRs offer benefits like easy access to medical records stored at some centralised storage, having access to detailed patient data and minimal hospital expenses. They also act as a mediator between healthcare workers and administrators. Moreover, they it records the history of medications the patient is stable with and of drugs that the patient is allergic to. This in-detail record helps in better compliances (Wali et al., 2020). EHRs and PMRs help generate big data related to patients. This data can be used for analysis. Test results, medical imaging and clinical reports also act as big data. This data is used by healthcare professionals for deriving the most suitable treatment for a patient by predicting necessary medical conditions in advance and by personalising healthcare services. The use of IoT with health data has made remote monitoring of health easy. It also includes the provision for alert systems in case of emergency. Due to its enormous scope, it has garnered a lot of attention and interest from researchers in recent years.

National Guidelines for Diabetes Care

According to several studies conducted by the Ministry of Health of Saudi Arabia, it was revealed that almost three-quarters of the population did not go for regular check-ups, two-thirds of them were obese, two-thirds did not do regularly exercise and 18 percent of the total population were active smokers. The highest number of deaths that take place due to noncommunicable diseases occurred in young people. Due to poor efforts from the government and the Saudi people, there is concern that the number of diabetic patients will double 5 million to 10 million (MOH, 2015) (). To detect and diagnose illnesses, the Saudi government initiated many healthcare programs that would support the long-term mission of the government's Vision 2030. The program sought the involvement of 24 State governments and their agencies to make possible the realisation of the aims of Vision 2030 and to achieve the 96 strategies outlined in the Vision 2030. These programs had the sole objective of promoting good health and reducing the health risks associated with chronic diseases like diabetes (SaudiArabia, 2016). Two such models were the healthcare model and a new institutional transformation, both of which had a focus on developing primary healthcare, since then prevention of diseases can be initiated at primary level. The success of such models is possible only when they have usability in detecting the risk factors associated with diseases and the on-time diagnosis of chronic diseases in the country. So, this raises the need to have a national portal program which can recognise patients at risk and those who are asymptomatic (Gosadi, 2019).

Integration of Diabetes Care into the Existing Healthcare System

A study revealed that almost 50 percent of diabetic patients in Saudi Arabia were undiagnosed and among them, 20 to 30 percent developed complications even before getting diagnosed (Al-Rubeaan et al., 2015). Therefore, a better screening approach is required in the country for timely detection and diagnosis. Currently, there are many assessment tools that are used for predicting diabetes based on genetic disorders. These methods are more convenient than blood screening tests.

Currently, diabetic patients are being looked after by general practitioners, interns, and endocrinologists. Diabetes care includes the involvement of many medical disciplines due to the complications it causes, thus it is necessary to set up specialised diabetic clinics and centres that provide specialised treatment to diabetic patients (Al-Rubeaan et al., 2015). Around the globe the treatment has shifted its focus to primary levels, i.e., at early-stage detection and diagnosis. However, in Saudi Arabia, patients are still receiving treatment at higher levels, which makes it impossible to treat the disease at an early stage. Not many studies have focused upon the treatment given to Saudi diabetic patients. Al-Rubeaan et al., (2015) conducted a study aimed at assessing the medical system that provides treatment and care to diabetic patients. Although the government tried to cover most of the expenditure of the disease, it could not meet all the costs. Providing cost-free glucose monitoring was impossible for the healthcare system, thus forcing the patients to use at-home glucose monitoring. Government hospitals were not able to provide all treatments required to patients due to the high rates of complications in diabetes. Private sector hospitals also need to be involved to tackle the country's healthcare demands. Only about 2 percent of the total medical services given to patients in Saudi are covered by health insurance (Al-Rubeaan et al., 2015). The Saudi government should encourage the role and use of health insurance policies, involving the private sector as well, and thus improving healthcare services in the kingdom.

Table 2.2: Objectives covered in the references and the span of publication year of the studies

Objectives	References	Authors	Years of Publication
Capacity to diagnose diabetes	Al-Hanawi et al., 2018 (MOH, 2015) Al Slamah et al., 2017	Al-Hanawi, Alsharqi, Almazrou, and Vaidya. Ministry of Health Saudi Arabia. Al Slamah, Nicholl, Alslail, and Melville.	2017, 2018
Capacity of healthcare workers	(MOH, 2015)	Ministry of Health	2014
Total strength of healthcare system in the country	Asmri et al., 2020 (MOH, 2015)	Asmri, Almalki, Fitzgerald, and Clark. Ministry of Health	2014–2020
Pilot experience for increasing patient adherence to treatment	AlQarni et al., 2019 Alqarni et al., 2019	AlQarni, AlQarni, Naqvi, AlShayban, Ghori, Haseeb, Raafat, and Jamshed. Alqarni, Alrahbeni, Al Qarni, and Al Qarni.	2019, 2019
Existence of electronic medical records	AlMarshedi et al., 2014 Wali et al., 2020	AlMarshedi, Wills, and Ranchhod. Wali, Alqahtani, Alharazi, Bukhari, and Quqandi.	2014, 2020
National guidelines for diabetes care	(Saudi Arabia, 2016) (MOH, 2015) Gosadi, 2019	Saudi Vision 2030 Saudi Ministry of Health Gosadi	2019–2020
Integration of diabetes care into the existing healthcare system	Al-Rubeaan et al., 2015	Al-Rubeaan, Al-Manaa, Khoja,Al-Sharqawi, Aburisheh, Youssef, Alotaibi, and Al-Gamdi.	2015

2.5.4 Conclusion

Diabetes one of the major causes of global mortality. If undiagnosed, diabetes may result in permanent disability or even death. The Kingdom of Saudi Arabia is affected by this disease, with diabetes one of the most challenging health issues faced by the citizens of the country. Although there have been many improvements to the Saudi Arabian healthcare system over the past two decades, many challenges still remain. The country has still many goals to achieve. The above sections provide insights into the shortcomings of current healthcare infrastructure and previous research regarding the Saudi Arabian healthcare system and the presence of diabetes self-care provisions. Improvements in the national healthcare system to deal with the control and treatment of diabetes must be the target to be achieved in the next few years. The country must be ready to face the challenges of diabetes as its impact is growing steeply. All the shortcomings of the existing healthcare system towards tackling diabetes should addressed as soon as possible. Since, one of the main purposes of this research is to assess the level of self-care among Saudi diabetic patients, an effective and a state-of-the-art diabetic self-care system should be developed providing diabetes self-care information to patients and a way to keep a track of the disease and to manage and control the spread of diabetes across Saudi Arabia. Additionally, a strategy should be developed to educate the diabetic patients about diabetes self-care.

2.6 Summary

This literature review chapter has identified important findings during the process of analysing different tools and techniques in the field of e-health, modelling and systems requirements engineering. This review chapter began with a basic outline of e-health in the context of process modelling and attempted to offer a comprehensive idea about e-health by examining and presenting numerous efforts in the literature. This chapter also summarised the modelling tools and techniques and the research gap in the field of e-health. The extent of readiness of Saudi Arabia for diabetes healthcare was also discussed through a systematic review.

Chapter 3 – Methodology

3.1 Introduction

The aim of this study is to seek ways to reduce the prevalence of diabetes in Saudi Arabia using an e-health-based self-management system for diabetic patients. To accomplish the aim within the assigned resources and time, it was crucial to use specific research methods and techniques to detect, evaluate, choose, and manage information about the planned study topic. This chapter describes the study philosophy, study approach, study design, research approach and research processes chosen for the thesis and the justification for choosing these tools and techniques. This chapter also describes the methods used for the collection and analysis of quantitative and qualitative data and focus group studies to align information systems requirements with the development of e-health. Thus, this chapter addresses the "WH" questions: "what" and "why" of the chosen tools, techniques and practices and aspects of "how" the investigation methods and procedures were applied are described in this thesis (Chapters 4 and 5).

The specific context of this research was the proposal and validation of an appropriate e-health model for personalised diabetes care and management for the diabetic patients of King Abdulaziz Medical City, Jeddah. This study aimed to propose and validate the most appropriate e-health model for better-personalised care and management of diabetes.

The aim had five components, as listed below:

1. A focus group session with stakeholders about personalised diabetic care and management process. This was aimed at identifying the inputs for modelling the e-health requirements in this aspect of care, with this session leading to the identification of processes and systems requirements for the study.

2. A quantitative questionnaire survey of diabetic patients in the Jeddah area was conducted to identify the diabetes patients who were using any e-health-based personalised diabetes management.

3. Using the identified inputs from the focus group session and models proposed in the literature, some possible models were derived which could be applicable in the case of Saudi Arabia.

4. Appropriate selection criteria were used to select the best model for implementation.

5. To implement and validate the finally selected model in King Abdulaziz Medical City, Jeddah through the collection of data on the outcomes.

3.2 Research Philosophy

The phrase "study philosophy" describes how the study data about a phenomenon is gathered, examined, and applied. Zhang et al. (2021) describe philosophy to conduct research as how understanding and learning are created and the important kind of research knowledge. Furthermore, the philosophy to conduct research requires considerable assumptions on how to understand the world of investigation and research and how to assist the planned investigation strategy, objectives, aims, and investigation methodologies and methods. According to Tesar (2021), the philosophy to conduct research is important in that it is essential in establishing how to deal with a study problem and influences how to collect study data and complete research.

The characteristics of the target group of the study are important in determining the research philosophy. This is due to the humanistic and ethical elements involved in research. The target groups of this research are the patients and experts of e-health in Saudi Arabia. This study tried to evaluate the extent of e-heath adoption and its impact on diabetes self-management outcomes in relation to what was required. The Saudi people have unique characteristics as was described in the Introduction section. These characteristics may affect their perceptions and attitudes about e-health and its use for the self-management of diabetes. Thus, the source of knowledge may be different from what is obtained from another group of a different country. Hence, realism is the only possible research philosophy related to this research.

Starostin (2021) identifies four different kinds of study philosophies: interpretivism, positivism, pragmatism, and realism. These philosophies of doing research could be realised across the senses of axiology, epistemology, ontology, and data-gathering methods as shown in Table 3.1. Madden (2021) discusses the examiner's point of view and how they could conduct research. This section concentrates on the research philosophy of realism, since the other three philosophies to conduct research were not aligned with or in the scope of this study. Table 3.1 provides a brief assessment of study philosophies about axiology, epistemology, ontology and data-gathering tools and procedures.

Table 3.1: The contrast of investigation philosophies

Components	Positivism research philosophy	Realism research philosophy	Interpretivism research philosophy	Pragmatism research philosophy
Ontology: The scientist's point of view of the kind of existence	External research, research aims and unbiased community actors.	Do the research aims and objective happen individually of individual feelings and attitudes or understanding of their reality (presence), but then are understood through social training?	Publicly assembled, individual, might change, numerous.	Exterior, several points of view were selected to best facilitate resolving of study question.
Epistemology: The scientist's perspective on what qualifies as appropriate knowledge	Only visible events can provide reliable data and facts. Concentrate on causation and generalisation, decreasing occurrences to their most basic components.	Obvious events provide reliable information and facts. Insufficient data leads to sensational inaccuracies (direct realism). Phenomena, on the other hand, produce experiences that are easily misinterpreted (critical realism). Concentrate on describing within a context (or several situations).	Social experiences and individual meaning focus on the specifics of the issue, the reality underlying the specifics, and the subjective meaning that motivates acts.	Depending on the study questions, either observable occurrences or subjective meanings can yield appropriate knowledge. Emphasis on useful applied research, incorporating multiple perspectives to aid in data interpretation.
Axiology: The scientist's perspective on the significance	The investigator is unbiased in the study data and provides an	Research is value-laden; the researcher is biased by world	Research is subjective because the researcher is a	When it comes to understanding findings,

Components	**Positivism research philosophy**	**Realism research philosophy**	**Interpretivism research philosophy**	**Pragmatism research philosophy**
of values in the study	objective posture while conducting research.	views, cultural experience and upbringing. These will impact the research.	portion of what is being studied and cannot be detached.	values play a big role, with the investigator embracing both objective and subjective viewpoints.
Gathering data: Method to collect study data and is mostly used in scientific research	Quantitative, but focus groups can be used. Highly organised, huge samples, measurement.	Quantitative or focus group techniques must be appropriate for the topic matter.	Qualitative study, small sample size, in-depth investigations.	Focus group and quantitative techniques, mixed or multiple method designs.

Study data is frequently acquired in the applicant's environment during the qualitative research process, which incorporates evolving patterns and methods. It entails inductive data analysis to construct a theory from details, and the researcher interprets the obtained facts (Hurliman, 2019). As a result, inductive reasoning was a big part of the focus group and quantitative studies of this research.

Focus group and quantitative studies verify hypotheses by looking into the interactions between variables and different instruments can be employed to quantify variables (Hurliman, 2019). Statistical approaches may be used to evaluate the collected data. Logical thinking is generally the focus of this style of research. The pragmatic methodology can be used to convey the employed study philosophy and the usage of mixed techniques is aligned well by using the rationalist paradigm (Ahlskog, 2020; Žukauskas et al., 2018; Dougherty et al., 2019). Moreover, according to Dougherty et al. (2019), it is also clear that the mixed-method approach has pragmatist roots. As a result, this study follows the rationality philosophy by employing a mixed-methods approach that includes both quantitative and qualitative research.

3.3 Research Strategy

Both governments and e-health businesses in Saudi Arabia and governments have been constantly confronted with new issues related to understanding e-health systems performance, capabilities and effects as new and complex information technologies and e-Government services emerge. Furthermore, the spread of information over the internet, the broadcast of ordinary non-work-related systems and societal media and the customer responsiveness of the numerous gadgets allowed with various e-health technologies and applications have all contributed to technology being an integral part of the public's lives.

Because of this fast-changing environment, information systems researchers frequently run into situations where existing theories and findings are inadequate to explain or provide substantial insight into the establishment of effective e-health solutions in the Saudi Arabia context. Mixed methods and focused strategies provided a way for information systems and e-health researchers to deal with such situations and, as a result, contribute to theory and its application. Table 3.2 lists a variety of reasons why a mixed-technique approach is preferable to a single-method approach (Žukauskas, et al., 2018; Moon et al., 2019; Hasyim et al., 2020; Zhang et al., 2021).

Table 3.2: Focus group and mixed methods

Research method elements	**Description**
Completeness	This method is used to ensure that a full image of a phenomenon is captured.
Complementary	To develop a complementary point of view on the same associations, mixed and focused approaches are employed.
Growth	An e-health information system is used to describe or expand on the development of part of a previous study.
Developing	One group's suggested questions come from a previously group's inferences or one element supplies hypotheses to be tested in the next.
Recompense	It compensates for one technique's flexibility by employing another.

Research method elements	Description
Confirmation	It is utilised to evaluate the consistency of inferences drawn from a single technique.
Variety	An e-health information system is used to compare and contrast different perspectives on a similar trend.

Three important features of the mixed-methods approach in this study demonstrate the benefit of doing alignment research in the context of the e-health sector in Saudi Arabia. For starters, mixed methods studies make it possible to address multiple research issues at the same time. However, both focus group and quantitative methodologies can be used to answer similar research questions, while qualitative methods are more commonly used in e-health research and other social sciences to gain a deeper insight into a phenomenon.

Second, compared to a single method or worldview, a mixed-methods investigation gives more comprehensive judgments. System requirements engineering in the context of e-health research that uses complex focus group and quantitative methodologies can provide useful insights into a variety of e-health occurrences. Finally, mixed-methods and focus group research allows for a larger range of divergent viewpoints. When looking at mixed-methods or focus group methods, an investigator might notice that the quantitative and qualitative parts provide different outcomes, such as unpredictable and complementary opportunities.

3.4 Modelling Techniques

Some details of a modelling technique given in the Computer Science Department (2010) were found appropriate for this study. Modelling approximates analysable real-world observations. Although this is a general definition of modelling, in this research, the term is used to explain how a personalised diabetes care model can be implemented using e-health tools. GOMS (goals, operations, methods, and selection) is the most researched task analysis model for user-specific tasks and their analyses. This modelling technique was developed by Card et al. (1983). The model consists of the following steps:

a) The user goals to be achieved. In this research, the users are the diabetic patient, the doctor and other healthcare providers like nurses and volunteers and the hospital which implements the e-health system. The goal to be achieved is an e-health system for personalised diabetes care and management to keep the disease under control.

b) The operations the users need to do. In this step, these are what all the users listed above need to do at different stages (foreseen as well as emergencies) to achieve the goal of obtaining an e-health system for personalised diabetes care and management.

c) The sequences of operations to achieve the goal. The operations need to be sequentially arranged so that different users do not act at cross purposes. The model should diagrammatically describe this sequence. At this stage, different types of e-health model diagrams for personalised diabetes care and management might be obtained for considering different sequences of operations.

d) Selection of the most suitable model from the different models that are available. To select the most suitable model, certain criteria are fixed and the models are evaluated for these criteria to select the most appropriate model.

e) This model was tested in King Abdulaziz Medical City for real-time evaluation. The expected outcome is the most appropriate e-health model for personalised diabetes care and management for implementation across Saudi Arabia, which was the aim of this research.

The outcome of this study is essentially a diagrammatic description of the e-health system for personalised diabetes care and management. Five types of diagramming techniques are described in Open Learn (2018): data flow diagrams (DFDs), use case modelling, activity diagrams, entity–relationship diagrams, and state machines. Four of these (each technique except DFDs) are included as behaviour diagrams by Jun et al. (2010).

DFDs are representations of a flow of data in a process or a system like an information system. They also indicate the inputs and outputs at each stage of the flow. There is no control flow or decision rules in these types of diagrams. A use case diagram is primarily a dynamic or behaviour diagram. A use case diagram models the functionality of a system for which actors and use cases are utilised. Use cases are a set of actions, services and functions that the system needs to perform. A system is something being developed or operated like a website. The actors are people or entities operating under defined roles within the system (Smartdraw, 2019).

An activity diagram is a control flow diagram to capture the activities of a system and this can be used for modelling workflow and using activities (Totorialspoint, 2019). An entity relationship diagram is used for database structural diagram. It is not suitable for this research. A state machine diagram is used for describing the discrete behaviour of a part of a system using finite state transitions. This model is also not applicable to this research because it deals specifically with designing a database not a full system.

Some of the models described in this section have been used successfully in healthcare applications. Role activity diagramming was used for a complex process of cancer care and registration in Jordan by Abu Rub et al (2008). A unified modelling language (UML) profile approach was used by Raghupathi and Gao (2007) for modelling web services in healthcare. A case diagram was used to develop e-health tools for promoting healthy habits among obese and diabetic kids by Song (2016).

Some e-health models found in the literature could be useful to frame the model in this research. These models are presented below in Figure 3.1.

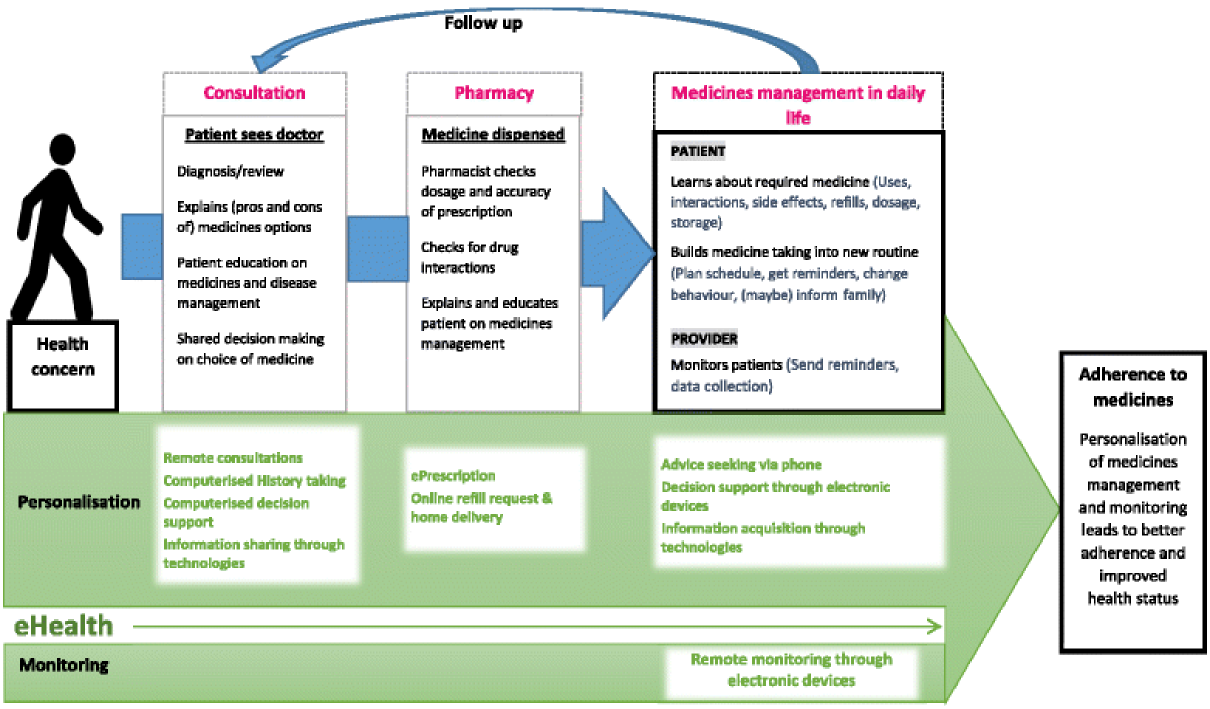

Figure 3.1: Model 1 (Car et al., 2016)

Source: Car et al. (2016)

In Model 1 (shown in Figure 3.1; Car et al., 2016), the important components of self-management of diabetes by patients are remote consultations for diabetic patients when a visit to the physician is not required, automatic messaging for updating the knowledge of patients to facilitate self-management and reminder messages of tests, medication, lifestyle changes, hospital visits and emergencies from the physician, and feedback of test results and other patient variables to the physician. These features will form part of the proposed models of this study also.

A cloud-based system could also be used for e-health modelling, as shown in Figure 3.2. Model 2 illustrates the REACTION project (Thestrup et al., 2012), which uses a mobile and cloud-based platform to provide healthcare services to diabetes patients.

Exploring new Care Models in Diabetes Management and Therapy with a Wireless Mobile eHealth Platform 3

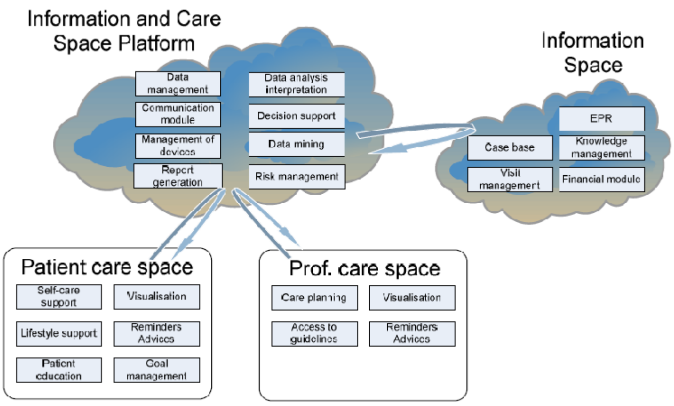

Fig. 1. The REACTION platform integrates information and care spaces.

Figure 3.2: Model 2: The REACTION platform

Source: Thestrup et al. (2012)

The diagram in Figure 3.2 shows the data and other requirements at each level. Cloud computing is used for data collection, mining, analysis, management, decision support, communication, reports, devices management and risk management. The REACTION project was initiated by the European Commission in 2012, with the aim of developing a plan to improve the long-term management of diabetes. Wireless technologies are used to continuously monitor blood glucose. It is also used for clinical monitoring and intervention strategies. Monitoring and predicting related disease indicators are also part of the program. The automated closed-loop delivery of insulin was ultimately implemented. The outcomes to be achieved were the creation of an intelligent, interoperable, cloud-based platform to provide integrated, professional management and therapy services to diabetes patients in healthcare regimes. These services consist of professional decision support for in-hospital environments and safety monitoring for medication dosage and compliance as well as the long-term management of patients in primary care settings. There is also a provision for the care of patients with acute diabetic conditions. Finally, support for self-management and changes in lifestyle are provided to diabetes patients. The main target group for the project are insulin-dependent patients. The basis of interventions improves the efficiency of continuous blood glucose monitoring and the safe control of glycaemic levels for improved management of insulin therapy and adjustment of basal/bolus doses. The REACTION platform is used for wireless connections to sensors and monitoring devices in the physical surroundings of patients. Feedback is given to the patient and informal carers, who might be relatives or neighbours. Feedback is also given to healthcare professionals and emergency teams in the hospital. The modelling system envisaged in this thesis is not as complicated as in the REACTION project. But one of the proposed model uses cloud computing as a means of data storage.

In a meta-analysis, Greenwood et al. (2017) note that mobile phones and secure messages are used as the primary means of diabetic self-management in the reviewed works. The reviewed works tested four interventions of diabetes self-management: two-way communication, tracking and analysis of patient-generated health data, general or customised education content, and automated or live feedback. Blood sugar as A1C was the outcome measured in most cases. The self-care behaviours monitored were healthy eating, active lifestyle, monitoring, adherence to taking medicines as per prescription, risk reduction, solving any problems during self-management and healthy ways of coping with life with diabetes. Mobile-enabled diabetes self-management linked to hospital services seemed to be the best and most practical option.

Based on a review, a mobile-based diabetes management program was presented by Shan et al. (2019). This is presented in Figure 3.3.

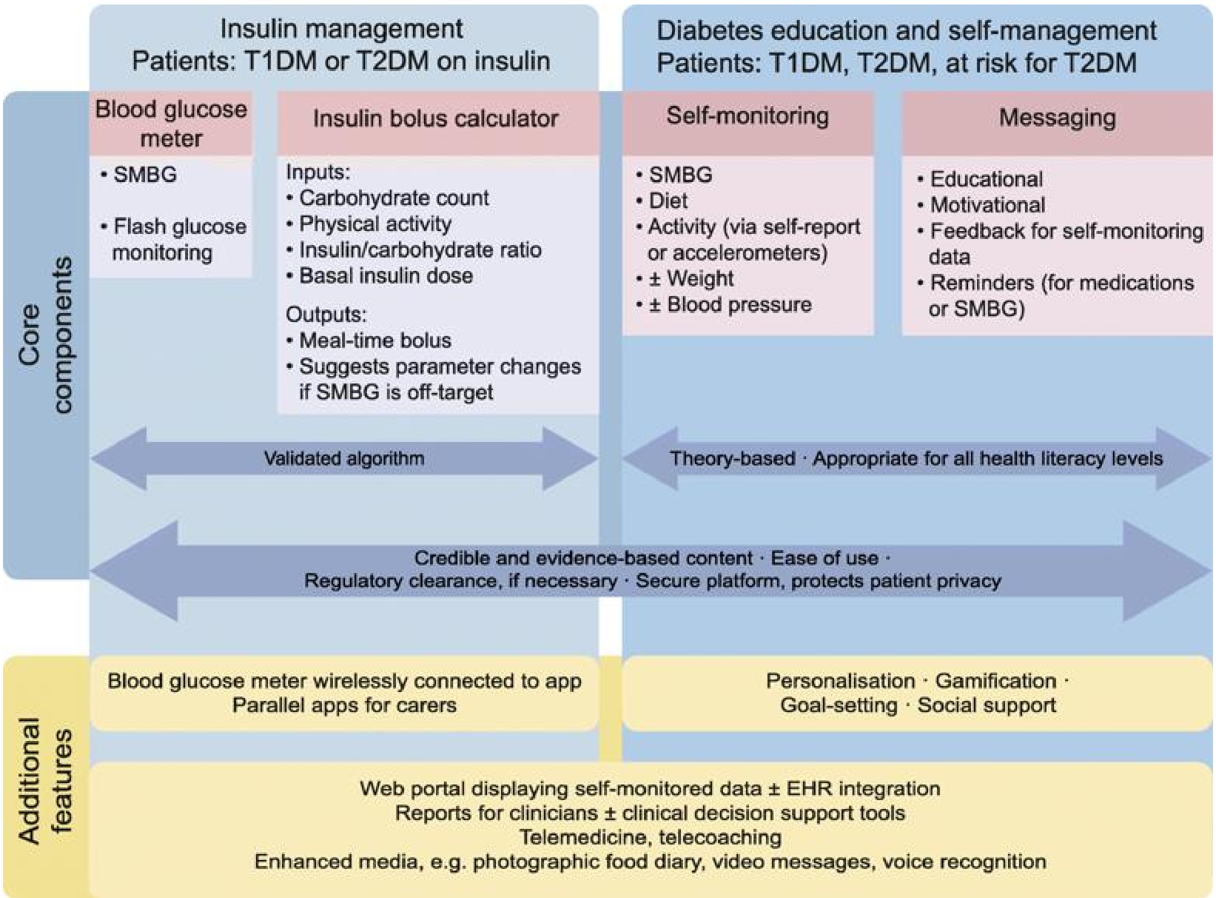

Figure 3.3: Model 3: Using cloud computing and the Internet of Things

Source: Shan et al. (2019)

The use of a cloud-based e-health system for remote areas was designed and validated using focus group interviews by Miah et al. (2017), utilising the socio-technical design approach of Gregor and Jones (2007). Its components are purpose and scope, constructs, principles of form and function, artefact mutability, testable propositions, justificatory knowledge, principles of implementation and expository instantiation. The authors explain their design using these components. All records from the doctor, patient and local healthcare worker are placed in the cloud for multipoint access as required. This work provided some assistance in designing the system in the present research.

Al-Taee et al. (2015) designed, implemented, and obtained high patient acceptability for the mobile-based self-management of diabetes. In this system, multiple types of care were determined using the remote collection and monitoring of patient data. There was a provision for personalised customised feedback through smartphones. This made possible real-time clinical interactions and personalised feedback for the needs of the specific patient using both historical and current data as well as compliance with treatment plans. Using rule-based indicators, appropriate warnings and support were provided through the feedback services. The physical layer of the platform contained wireless nodes. These nodes had a set of medical sensors which were linked wirelessly to a mobile device. The nodes were also connected to a web-based application layer using a telecommunication infrastructure which already existed. Additionally, technology-enhanced peer support was useful for personalised diabetic self-management in the findings of Heisler et al. (2019).

There is good scope for use of mobile-enabled e-health systems for self-management of diabetes. Hence, one of the four models suggested from the findings of this research is m-heath.

Overall, the above review illustrates that case diagramming is a suitable method of constructing and presenting the model in this research. Mobile phones with cloud computing are the most suitable tool. Peer support, remote access, and cultural compatibility were additional points to consider for proposing mobile-enabled e-heath models with cloud computing in this research. This seems to be the most promising model for the Saudi context.

Based on these considerations, the research design and procedure of the study are described below. The research design is the plan for logically and coherently integrating the various study components. The research design is the strategy that the study uses to answer the research questions (Ahlskog, 2020; Žukauskas et al., 2018; Dougherty et al., 2019). The goal of the research design is to ensure that the subject under investigation is accurately assessed, and that the study's scope was determined.

As illustrated in Figure 3.4, the research design for this study is separated into four levels. The first level entails a broad evaluation of the literature on e-health in the context of system requirements engineering and the context of Saudi Arabia's environment. This contributes to a broad understanding of the research topic that is being investigated on a bigger scale. The second stage is the focus group research, explaining the design of focus group discussions as a method of data collection. The focus group results are used for the quantitative questionnaire survey in the third stage. In the fourth stage, the conclusions are drawn and the scope for future research is derived.

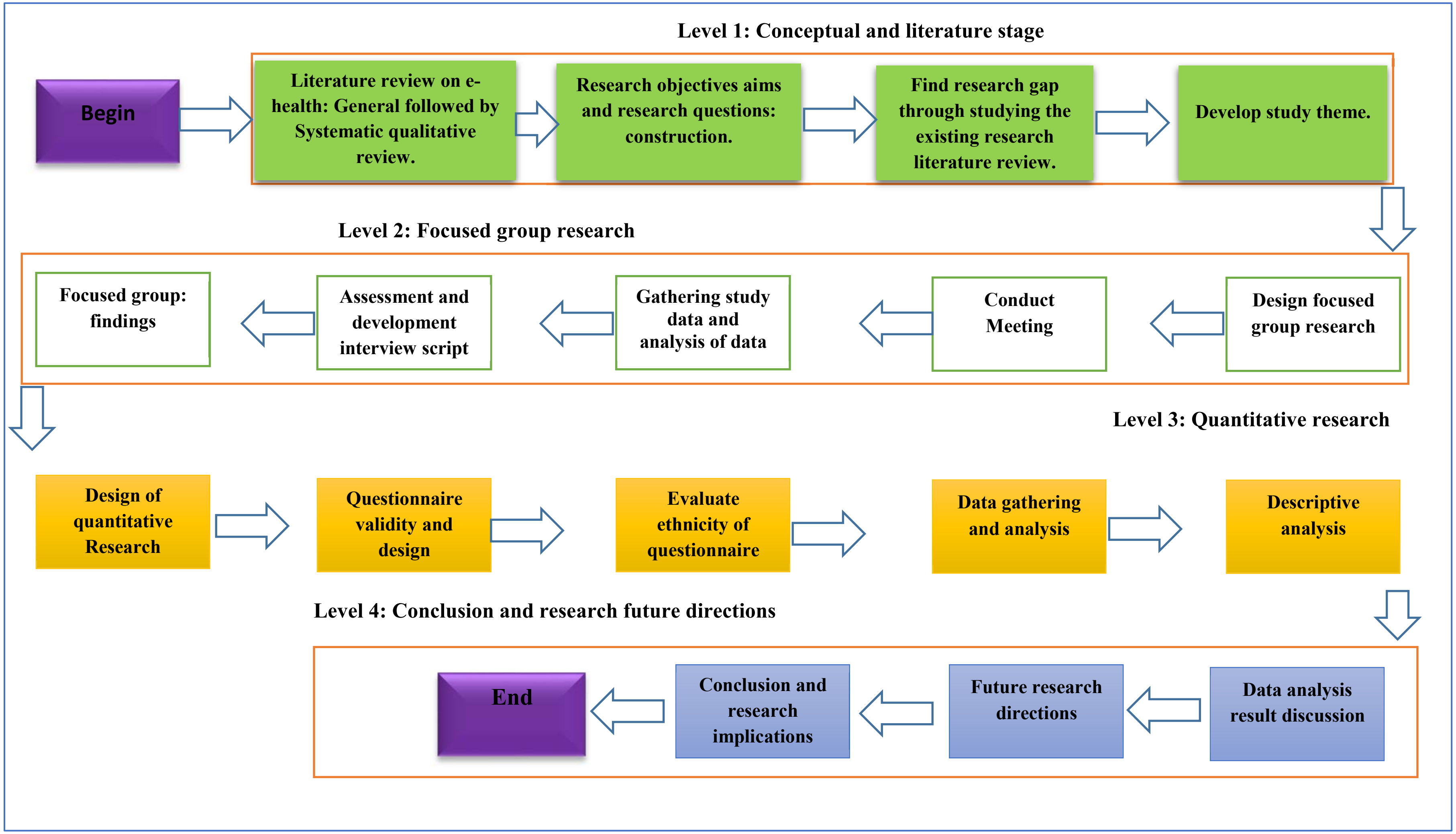

Figure 3.4: Research design for this study.

3.5 Research Method

This section explains mixed-methods research and how it can be applied to the e-health sector. A mixed-methods strategy is a study design that incorporates numerous research approaches into one perspective. Sahin and Öztürk (2019) state that multiple-methods research can be divided into two categories: first, mixed-methods research; and second, multi-method research. In many corporate fields, however, mixed-methods and multi-method research are used interchangeably.

Theoretically, there are major distinctions between the two. Investigators utilise two or more study methodologies in a multi-method research design, although they might limit the research to a single worldview. For example, an investigator might use the study of an applicant's traditional history and judgement to research the design and implementation of a new information system in a corporation.

Sahin and Öztürk (2019) propose a multi-methodology that incorporates two or more mixed-method techniques, such as using both a survey and interviews in a research project or employing a multi-methodology that includes more than two methods. Furthermore, multi-methodology is commonly defined as the combination of two distinctive procedures within the qualitative paradigm as two unique forms of multiple methods study. A multi-methodology study, according to the authors, can be accomplished using both a single technique and numerous separate methods. The multi-method strategy used in this study is shown in Figure 3.5.

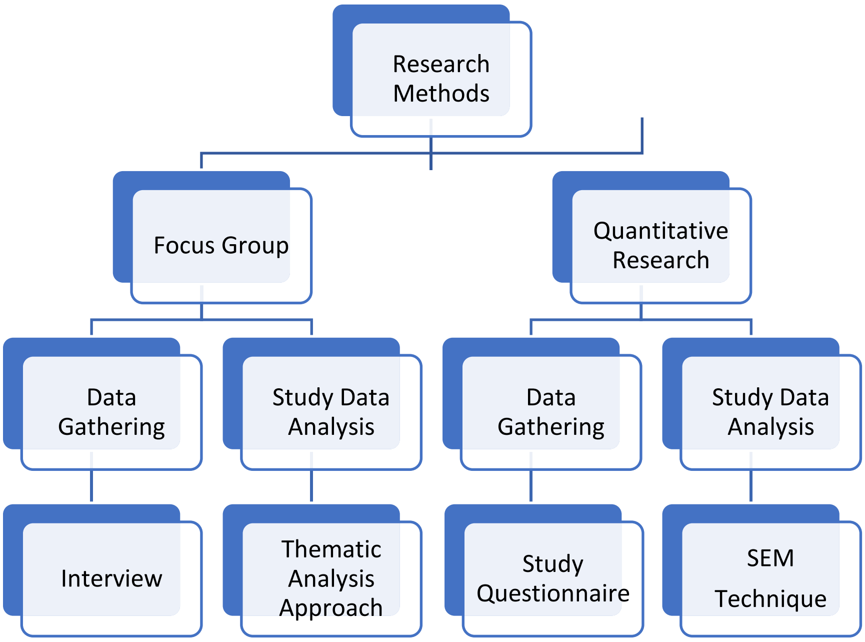

Figure 3.5: Research methods used in this study.

3.6 Research Design

This research uses a mixed approach consisting of quantitative and qualitative methods triangulated using published literature. The research process consists of five components and a few additional steps specific to this research. The five components are:

1. A focus group session with stakeholders about personalised diabetic care and management process.
2. A quantitative questionnaire survey of the diabetic patients in King Abdulaziz Medical City, Jeddah area to identify the diabetes patients currently using any e-health-based personalised diabetes management.
3. Deriving possible models using the identified inputs from the focus group sessions and models proposed in the literature that were applicable in the context of Saudi Arabia.
4. Appropriate selection criteria used to select the best model for implementation.
5. Testing and evaluation for validation of the finally selected model.

The description of the components follows.

3.6.1 A Focus Group Session with Stakeholders about Personalised Diabetic Care and Management Process.

A focus group session with stakeholders about personalised diabetic care and management processes was conducted. This was aimed at identifying the inputs for modelling the e-health requirements in this aspect of care. This led to the identification of the processes and systems requirements for the study.

In a qualitative study, a variety of conversation types are utilised (Hennink and Kaiser, 2021; Treadwell et al., 2021). To gather qualitative data in this study, a semi-structured conversation technique was chosen above other accessible discussion techniques. Discussion cards were used to conduct face-to-face discussions with e-health professionals. A discussion card is a cue card that offers an abstract level of information regarding the subject being addressed throughout as well as information that aids in the efficient and effective direction of the discussion (Hennink and Kaiser, 2021; Treadwell et al., 2021). Discussion cards, containing one question and possible sub-questions depending on responses, were prepared in advance, as listed, and described below.

Different cards were used during the discussion process with the e-health experts to guarantee that the focus of the discussion remained on the assessment of the elements in the field. In addition, the cards included a list of e-health elements that have a favourable impact on the health environment in Saudi Arabia.

During the discussion process, the first card greeted the focus group; the second card inquired about the applicant's background, schooling, and knowledge; the third card gathered information on the applicant's knowledge of health and information systems in the context of e-health; and the fourth card served as the discussion rules. As a result, qualitative data could be analysed to find new and hidden elements connected to information systems and other sectors of e-health (Wittstock et al., 2022; Zörgő et al., 2021; Levitt et al., 2021; Braun et al., 2021).

Hu et el. (2022) and Peat et al. (2022) argue that researchers should use a semi-structured discussion strategy. It should begin with a welcoming message to the applicants and common information on the meeting procedures that are going to be applied. Researchers might ask open-ended questions about the study theme during the semi-structured discussions. As a result, a semi-structured discussion is ideal for gathering qualitative information. In order to comprehend applicants' perspectives on the subjects under examination, the researcher uses inductive reasoning. Discussions are useful for determining the date of the meeting, the location of the meeting and the procedure to conduct the meeting.

There are two types of sampling strategies: hypercritical data-sampling methods and likelihood sampling methods. To pick the sample based on the research objective or research goal, non-random sampling and non-likelihood data sampling techniques are utilised (Evitt et al. 2021; Braun et al. 2021; Islam and Aldaihani, 2022). The quantitative sampling method selects a section casually from a large set of data, whereas the qualitative sampling method aims to pick an accurate sample of applicants to aid in getting specific knowledge on how to solve the study questions. According to Islam and Aldaihani, (2022), qualitative studies try to explore problems linked to the study rather than simplifying study findings, hence casual data sampling is not acceptable in a qualitative study.

This study contacted a total of 25 e-health professionals from Saudi Arabia and 15 of them consented to take part. Each of the 15 applicants was questioned face-to-face for roughly one hour together as a group.

The focus group discussion was organised and completed through a series of questions, derived from the four research questions given in Chapter 1. The points listed for each question were derived from the review of literature discussed in Chapter 2. For this purpose, various points related to e-health systems, implementation by hospitals, adoption by patients, extent of compliance and factors affecting it, outcomes and the roles of various stakeholders were gathered from the literature. The points gathered were discussed with experts for their applicability in Saudi context. Those applicable in Saudi context were included and others were discarded. The included points were again reviewed for repetition, clarity, and appropriateness for focus groups by discussing them with friends. The finally revised set of questions with the points under each question are described below.

Q1. Let us assume the patient reported high sugar readings three times during the last three months' monitoring. He was not on insulin but only on diet management. There was no advice from the hospital on these readings. He knew something needed to be done immediately. If he was far away from the hospital, what was the solution?

The aim was to identify how situations in personal diabetic care could arise which would justify the introduction of e-health. Examples provided include:

- Aims of diabetes control: glucose levels inside the acceptable range, physical development, savvy eating.
- Means to achieve them: Insulin, planned diabetes medications, diet and exercise. No single means was satisfactory alone. Physical activity was important along with medication and diet control.
- Supports: Approach the diabetes human administration department, a monthly screening of glucose, and special care during the menstrual cycle and pregnancy.
- Things which might go wrong: Production of pressure-related hormones could raise glucose levels, result in cravings, which is commonplace activity affecting diet control. The solution was to work with the social protection gathering and take free lessons on a daily course of action. Sessions included information on what medications to take, how much time to evaluate the glucose and urine ketone levels, how to change medication estimations and when to call a doctor.

Q2. Could each diabetic patient please describe his/her experience in managing his/her diabetes at home. Were there any difficulties? How did you solve it?

The aim was to identify the possible difficulties of self-care which needed to be addressed in e-health modelling. Examples provided include:

- Comprehensive diabetes care plan: diabetes dinner plan, help from the social protection gathering through a gala plan, monitoring of blood glucose, heartbeat and cholesterol, nourishments developed from the beginning, wholegrains, chicken or turkey without the skin, fish, lean meats, and non-fat or low-fat milk and cheddar, water instead of sugar-improved refreshments.
- Manage problems with support: drugs help, cerebral pain medication to prevent a respiratory disappointment or stroke, social protection to solve the expense issues, side effects from medications.
- Psychological problems: Feeling pushed, desolate or incensed. Stress can raise blood glucose. Lose weight. Profound breathing, cultivating, going for a stroll, doing yoga, pondering, doing a leisure activity, tuning in to my preferred music, participating in a diabetes guidance program or care bunch. These were the strong ways to deal with adjusting to the pressure.

Q3: Could each friend or relative of a person with diabetes please describe the hardships they have been in when the patient experiences a problem. Describe the problem, how you were involved and how was it solved.

The aim was to explore how the difficulties identified in the previous question were reduced through the involvement of a close relative or a friend. Examples provided include:

- How diabetes developed: glucose in the blood was raised, did not deliver enough insulin, created no insulin, or had cells that didn't react appropriately to the insulin the pancreas produces; an overabundance of blood glucose inevitably dropped off the body in urine, the cells were not getting it for their fundamental vitality and development prerequisites, patients require instruction and abilities preparing to perform diabetes self-administration.
- Insulin needs: The glucose was either high or low or at some point, the two conditions existed in a solitary patient. The patient was exhorted to take insulin.
- Diabetes can affect renal function. Diabetes can likewise harm the kidneys and influence their capacity to channel squander items from their blood, recognised micro-albuminuria or raised measures of protein in urine, an indication that the kidneys are not working appropriately. Phencyclidine (PCP) would assess the diabetes patient for nephropathy to help forestall irreversible kidney harm or kidney disappointment.
- Diabetes can affect heart and nerve problems: diabetes made diabetic neuropathic or harmed the nerves, influenced warmth, cold, and agony, increasingly vulnerable to injury, would not notice these wounds and let them form into genuine diseases or conditions increasing.

Q4: Was there a possibility that e-health would have helped in these situations?

The aim was to examine how e-health can enhance self-care irrespective of close relatives or friends. Example provided include:

- E-health potential: e-health and m-health could be applied both in the administration and counteraction of diabetes and ought to be implanted in the continuum of anticipation, care and fixes. E-health can be significantly improved when ICT technologies are joined with proof-based conduct change mediations.
- E-health effects: doctors have less work and share information securely and successfully with accomplices. Not all social protection providers offer tele-health,

patients were getting progressively aware, offering patients the opportunity to design courses of action on the web.

- What was involved in e-health? Brisk and basic data sharing, e-health solutions develop joint exertion among restorative administrations providers while enabling patients to improve persistent outcomes and growing patient prosperity. Improved data straightforwardness to avoid pointless costs realised by duplicate evaluations and extra administrative undertakings, updating resources that might somehow be appended to partitioned IT and system upkeep.
- E-health facilitation: E-health instruments were getting logically notable for helping patients self-regulate wearisome conditions. E-health devices could encourage patients to expect greater activity in shared elements and might have manufactured revolves around self-organisation and obstruction care. The use of e-health gadgets can give a level of settlement to the two patients and providers. These instruments from any web skilled contraption can consistently give a method for unconventional correspondence, messages and illuminating, patients and providers to ask and answer requests at whatever point the planning was perfect, resulting in lesser loads for the specialist.

Q5: E-health with personalised management at home. What are your ideas about it?

The aim was to identify the requirements for modelling e-health for the personal home management of diabetics. Example provided include:

- Smartphones to aid e-health: smartphones, future medication, psychological wellbeing, administrations, help for patients and parental figures as far as self-checking. Smartphones and other individual gadgets could improve the openness to these informational indexes, help patients in social occasion data, own diseases, own circumstances more viably.
- Customisation of smartphone applications of e-health: e-health-related customised medication. Relatives and companions are key facilitators of clinical adherence helping ill-equipped individuals.
- Information connectedness of e-health facilitated by smartphones: e-health was more beneficial in a wide range of ways having one’s information connected to a thought of avoidance, their feeling of risk.

- The potential of e-health in T2D: With Type 2 diabetes, developments in e-health have shown potential for supporting patients with self-administration practices, specifically dietary and physical movement practices, and may bring about better diabetes results, for example, HbA1c.

Q6: E-health with personalised management at home – what are your thoughts about it?

The aim was to reduce hospital visits through e-health models using the identified requirements. Example provided include:

- Mobile applications to reduce hospital visits: mobile telephone (applications), self-administration of constant disease, versatile wellbeing (m-health) applications, of ability and procedure obtaining expanded in the portable application in addition to wellbeing directing gathering, other auxiliary results did not contrast among gatherings.
- Wellbeing, not just self-care; versatile wellbeing (m-health) applications for self-administration, improved ease of use and can be made sensible with versatile applications, control their wellness and wellbeing.
- Smart gadgets as e-health tools: different diabetes gadgets, insulin siphons and glucose meters, independent capacities in versatile applications, blend of most capacities fundamental for self-administration, fundamental for self-administration, blood glucose logging, insulin dose, starch estimation, exercise, designs, and visit and direct contact with human services suppliers on a cell phone application.
- M-health application portals: a quantity of openly accessible portable applications identified with diabetes and diabetes self-administration, exponentially, m-health included the utilisation and exploitation of a cell phone's centre utility of voice and short messaging service (SMS) just as progressively complex functionalities and applications including general parcel radio assistance (GPRS), third and fourth era versatile broadcast communications (3G and 4G frameworks).

Q7: What is the scope of integrating mobile phones in e-health for personalised care?

The aim was to identify variables for the integration of mobile phones in e-health for self-management/personal care. Example provided include:

- Negative variables affecting positive impact: compact prosperity (m-health), the difficulty of current therapeutic administration spending, a prerequisite for risky courses of action.

- Variables of implementation: m-health progressions, the restorative administration condition, improved results and essentially cutting down costs, buyers, m-health offered the assurance of improved settlement, progressively conspicuous personalisation. Wearables, shortly, improving patient selection and satisfaction, shortening fundamental courses of occasions, and growing the scale, speed, and solace of data get, m-health promised to have a transformational influence on human administrations.
- Variables of technological progress: m-health advancements in adjusting clinical fundamentals and improving part and patient responsibility were all around dynamically seen by underpins, analysts, contracts to investigate affiliations,
- Variables of expectations: m-health helped patient selection and support, productive starter culmination, giving progressively complete data on calm security and suitability, prosperity needs, overhauled convenience by diminishing assessment visits and through online examinations and assessments, helped inpatient preparing and consent necessities, and energised support and partial responsibility through refreshes and online surveys, patient assistants could arrange with each other, giving them social and energetic assistance.

Q8: Thinking of e-health for personalised care, what elements need to be included in such a system?

The aim was to identify the elements of a comprehensive e-health personal care system. Example provided include:

- Personal factors: the extent of commitment, progressively beneficial, having one's data, expectation, thwarted the headway of a steady affliction, own sentiment of hazard.
- Care perspectives: own sentiment of hazard, an individual could improve before a potential ailment, helped by e-health, commitment, use of genomic markers for customised drugs, careful and current partner, find elective frameworks, with various meds or through preventive strategies, including diet and physical exercise.
- What a comprehensive e-health system could do is supply people with customised data for better assessment of their wellbeing by including a sentiment of commitment, useful social changes, being the dynamic legends of their life, and not uninvolved recipients of others' decisions.

- Developments helping interventions: genetic and genomic developments, clinical qualities related to customised medicine, patients' understanding and responsibility concerning the need for and the subsequent use of these organisations.

Q9: How do these elements help personalised care in e-health management of diabetes?

The aim was to explore the exact ways in which the design elements identified above will help e-health self-management. Example provided include:

- Upgraded standards: modern devices by and large welcomed by patients as an upgrade to standard treatment, energised support from social protection providers or companions, and strategies of restorative administrations providers in self-care.

- The application offers: various applications offered tantamount limits and simply offered two or three limits in every application. Patients and specialists ought to expect greater activity in application improvement later on, at least 50 applications were moderate to satisfactory, multifunctional applications, convenience and accessibility features were insufficient.

- Support groups: internet-based diabetes self-organisation guidance was logically fruitful in improving glycaemic control and diabetes, when it appeared differently concerning customary thought, the ability to show up at various patients and the settlement of getting to the material at whatever point, lower the costs, internet-based diabetes guidance, and patient responsibility.

- Technological facilitation of outcomes: technology-engaged interventions had generally constructive outcomes, present second or no upgrades in haemoglobin A1C levels, diabetes self-organisation practices and diabetes self-sufficiency, a monetarily canny and nonstop conjunctive technique for treatment, prosperity and diabetes, information headways on both expectation and treatment of strength and weight gain.

The focus group session lasted about one hour, and the proceedings were recorded with the permission of the participants. The points generated from the focus group were used for the next step of manual modelling. The points discussed in the focus group are given in Appendix B. The qualitative data obtained from the focus group were analysed using the thematic analysis process prescribed by Braun and Clarke (2006).

3.6.2 A Quantitative Questionnaire Survey of the Diabetic Patients in the Area of King Abdulaziz Medical City, Jeddah to Identify the Diabetes Patients Currently Using Any E-health-based Personalised Diabetes Management.

For this quantitative questionnaire survey, diabetes patients in the Jeddah area were the target population. No precise data was available on their number. Jeddah had a population of 4.076 million in 2017, according to the World Population Review (2019). The national average incidence of diabetes was reported as 17.5 percent of adults in Arab News (2019). If this incidence level applies to Jeddah, the population of diabetic patients would be over 700,000. Even if the actual number was much lower, there would be enough number of diabetes patients for the survey.

The aim was to get at least 300 usable responses from the survey. Estimating a response rate of 25 percent was possible using websites with email and one follow-up, I needed to send the survey questionnaire to at least 1,200 participants. The study questionnaire was published on a research data collection website Qualtrics to gather the proposed study data, and potential volunteers were approached via my professional contacts in the health sector in Saudi Arabia as well as on social media platforms. The information was gathered over 10 months and 20 days (between 2021 and 2022). A total of 394 healthcare users, who used health services in any capacity, such as a visit to a local doctor or visiting a public hospital, were contacted to collect the data. However, just 80 percent of healthcare users took part in the survey, and we only obtained 315 responses. Data from 105 study participants were excluded for one of the following two reasons: missing data or responses from those who had never utilised healthcare products or services. The balance of 210 responses was used for analysis.

A survey technique was employed to acquire quantitative data from healthcare users for this study, which aided in the ranking of healthcare variables and related sub-factors. The questionnaire design, the pilot testing of study data, the sampling approach and participant information are discussed here. Analysing the quantitative data from a survey provides a numerical or quantitative research explanation of the opinions, attitudes, or trends of healthcare users (Bloomfield and Fisher, 2019; Almasy and Blangero, 20019).

A questionnaire survey is a simple low-cost way to collect data from a bigger population and it has a good level of dependability and validity for an authenticated and well-planned study questionnaire (Almasy and Blangero, 20019; Trehan et al. 2021; Wright et al. 2022). Neitzel et al. (2022) mention that in quantitative research, questionnaires help collect data by asking study participants to answer the same set of study questions and the data collected can be analysed using computer software. Investigators must be definite about the data to be acquired when planning and producing the survey questionnaire, which allows them to obtain accurate data. The process to design a study questionnaire is shown in Figure 3.6.

Figure 3.6: The process to design a study questionnaire.

King et al. (2021) state that establishing and producing a survey questionnaire entails a series of logical processes depending on the nature of the proposed study. The methods used to create and develop the questionnaire for this study are depicted in Figure 3.6.

Each of these steps used in this study is discussed in detail below.

- Step a: Verify the survey questionnaire's objectives, which includes prioritising the healthcare variables that are extracted from the literature of system requirements engineering and health sector and ranking their corresponding sub-factors to assess the success of e-Government in Saudi Arabia. The data were collected using a quantitative method and the factors were ranked using a mathematical mean value and pattern matrix.

- Step b: For survey questions on explanatory research, such as a participant's demographical information and healthcare background, a nominal scale is employed. All question formats and answers as well as any issues concerning the format were examined with the help of five quantitative study experts from the researchers' university.
- Step c: Determine the data-collecting methods, with the primary goal of the data collection being to obtain opinions and information on the survey questions from the research participants (Bauer et al., 2021; Spackman, et al., 2021; Moralez et al., 2021). Additionally, selecting the most appropriate data-collection method is critical for approaching the survey participants and obtaining adequate and reliable information to answer the study questions (Saunders, et al., 2009). An electronic survey questionnaire was found to be suitable for this research concerning obtaining data from healthcare users and businesses.
- Step d: Comprehending the wording of the survey questions, as the phrasing of each question must be carefully considered to guarantee that the survey participants' replies were genuine and could be assessed for their relevance to the variables intended to measure (Bauer et al., 2021; Spackman, et al., 2021; Moralez et al., 2021). The language of the survey questions must be simple, easy to understand and free from any ambiguity. The elements utilised in the survey questions were extracted from the literature review, and all of the questions were discussed with healthcare and requirements engineering specialists to confirm their applicability.
- Step e: The survey questionnaire stream and structure were established on an electronic standard and the questionnaire was evaluated by experts from the researchers' university (Ali et al., 2021; Zeng et al., 2021; Sabernezhad, 2021; Zhang et al., 2021). I ensured that the directions on how to fill out the responses to the questions were transparent and located in the appropriate areas of the questionnaire and that the survey questions planned for this research aligned with the research goals and objectives.

- Step f: After a thorough rewrite of the questionnaire to remove errors and ensure that the questions were appropriate and reasonably linked, the pilot testing for the questionnaire was conducted.
- Step g: Based on the pilot testing of the proposed questions, a well-formatted and well-organised copy of the research questionnaire was written. The subsequent arguments were addressed in the questionnaire amendments: the directions for filling out the research questionnaire were revised, 10 research questions were paraphrased, and 15 questions were removed based on the pilot findings. This stage aided in the preparation of the questionnaire's final copy. Furthermore, an acceptable period for completing the questionnaire was discovered, with a median time of 25 to 35 minutes.
- Step h: The questionnaire was circulated by posting it online on the website Qualtrics, and possible research participants were communicated with via social media platforms such as LinkedIn and Facebook as well as the hospitals in Saudi Arabia.

A copy of the questionnaire is included in Appendix A.

In this quantitative research, sampling strategies provided a variety of exploration methodologies that allowed the investigator to acquire the least amount of study data from any party rather than gathering research data from all conceivable situations (Sabernezhad, 2021; Zhang et al. 2021). The researcher gathered information from the healthcare sector in Saudi Arabia for this study. Because there was no trustworthy or formal data about healthcare and information system requirements engineering, the data sample was selected in a non-random manner, using the non-probability method of sampling. Due to the restricted time for study, restricted funds for research, society's accessibility, and healthcare constraints, it was not possible to collect research data from all residents of the Kingdom of Saudi Arabia.

Self-range data sampling is a non-probability method of data sampling in which research applicants are allowed to choose whether they want to contribute to the study (Sabernezhad, 2021; Zhang et al., 2021). The snowball data sampling approach is a non-probability method in which future defendants are chosen based on knowledge provided by the first participants who respond (Zhang et al., 2021). The snowball sampling technique involves researchers identifying study participants based on data presented on social and expert channels (Zhang et al., 2021). To reach the subjects in this study, I used self-selection sampling and the snowball sampling method. Study applicants were urged to find additional people who would be qualified for and interested in participating in the study and to distribute the invite through social media and email if they could.

3.6.3 Deriving Possible Models Using the Identified Inputs from the Focus Group Sessions and Models Proposed in the Literature That Were Applicable in the Context of Saudi Arabia.

The modelling techniques and e-health models from the literature are discussed in previous sections. These were used for developing some possible models for application in this research context. The context of this research is diabetic patients at King Abdulaziz Medical City, Jeddah, as outlined at the beginning of this chapter.

The principles of modelling technique as given by Card et al. (1983) were used along with some additional steps specific to this research. Each of the principles used are listed as follows:

a) The user goals to be achieved. Here the user was the diabetic patient, supported by the doctor and other healthcare providers like nurses and volunteers and the hospital which implements the e-health system. The goal to be achieved was an e-health system for personalised diabetes care and management to keep the disease under control.
b) The operations the user needs to do. These were what the user and the supporters identified in the previous principle needed to do at different stages (foreseen as well as emergencies) to achieve the goal of obtaining an e-health system for personalised diabetes care and management.
c) The sequences of operations to achieve the goal. The operations needed to be sequentialised for diagramming as well as for preventing different users from acting at cross purposes. The model should diagrammatically describe this sequence. At this stage, different types of e-health model diagrams might be obtained due to considering different sequences of operations, system design (see below) and diagramming techniques.
d) The system design, software and tools need to be defined. The system design was as per Gregor and Jones (2007):
    1. Purpose and scope: Mobile phones are convenient tools for interactions, communications and sending documents. Designing and utilising cloud computing or IoT for e-health might be useful for remotely located diabetic patients of the hospital.

2. Principles of form and function incorporating underlying constructs: The general development method (evolutionary prototyping) was described in line with design science research practice. For the artefact, a specific evidence-based technique was used for developing a clinical decision support system that provides lifestyle support to chronic patients matched to doctors' use of the same inference in diagnosis.
3. Artefact mutability: E-health services and implications for healthcare consultation and diagnosis in rural areas have been formulated around the context of utilisation of cloud computing resources. Smartphones, cloud computing and IoT models and system design for e-health services could be replicated for similar contexts and application areas.
4. Testable propositions: Evaluation with users in a focus group supports the argument that the design was workable in different conditions in remote locations.
5. Justificatory knowledge: The study detailed the e-health artefact concerning underlying smartphone, cloud computing and IoT and also socio-technical IS theory relevant to supporting healthcare professionals in their roles.
6. Principles of implementation: Testing and systematic evaluation including user acceptance were covered. Training and installation issues were considered, along with a discussion of wider issues concerning adoption. Technical details were given in detail in the results chapter.
7. Expository instantiation: The diagrams of all developed models (system prototype) are provided with evaluation.

Based on the above design principles, some e-health proposals for the personalised management of diabetes by patients of King Abdulaziz Medical City, Jeddah represented by the diagramming techniques described above. The above activities resulted in multiple models of achieving the goal. At least three types of models are possible:

1. Smartphone only with the sole support of the hospital.
2. Smartphone with cloud computing and hospital support for a wider reach to remote patients; and
3. Smartphones with the IoT and hospital support also for wider reach.

3.6.4 Appropriate Selection Criteria Used to Select the Best Model for Implementation.

Based on the systematic review of the literature, and the results of the focus group discussions and the survey of patients, the criteria for selection of the best model for implementation in the Saudi context was determined. Based on these criteria, the requirements of a e-health model for self-management of diabetic patients were specified. The specified requirements were used for proposing four different types of models. These models could be pilot tested, and the final model could be selected for gradual implementation in the whole country.

Acceptance rates by the users was used by Biancone, Secinaro, Marseglia, and Calandra (2023) as criterion for selection of the best e-health model from multiple case studies using technology acceptance model. Extent of trust on the security was used as a criterion by (Bahtiyar & Çağlayan, 2014) to select the best model out of different e-health systems.

A positive effect for tailored message in promoting physical activity was observed by Sabooteh, Feizi, Shekarchizadeh, Shahnazi, and Mostafavi (2021) in an e-health system tested on students. Out of the four models proposed, the cloud-based e-health systems may offer a good option, as it could increase platform scalability and quality of services with a possibility of application in chronic diseases like diabetes, as was noted by Vilaplana, Solsona, Abella, Filgueira, and Rius (2013).

The above examples show that many parameters could be included for selection of models. These parameters may be related to the user (any user out of various stakeholders) or any component of the system. In the pilot testing stage of the models, the various parameters identified from the survey and the focus groups will be used as selection criteria.

3.6.5 Testing and Evaluation for Validation of the Finally Selected Model.

The finally selected model is to be implemented for diabetes patients in King Abdulaziz Medical City, Jeddah. The data on outcomes was collected. Based on the results, a package for successful implementation in Saudi hospitals are to be developed. The outcome will be the most appropriate e-health model for the personalised care and management of Saudi diabetes patients, which was the aim of this research.

An assessment of e-health readiness of hospitals is one of the aspects to be tested for evaluation of the selected models. Core readiness, technological readiness, societal readiness, policy readiness, engagement readiness, effort and performance acceptance and use readiness were used as the framework for testing and evaluation of a e-health model from public hospitals by (Beebeejaun & Chittoo, 2017). Awareness of e-health concept, ability to use a computer or smartphone and internet were also evaluated. Using the same components, Rezai-Rad, Vaezi, and Nattagh (2012) found technological readiness as the most important, followed by core readiness, social communication readiness, and engagement readiness. These two and many other papers include many items in the readiness constructs. The framework can be used to assess the model's suitability for patients, hospitals, healthcare professionals and other stakeholders. This framework with adaptations to this study could be used for evaluating the four models and selecting the best one for implementation.

3.7 Ethical Considerations

The need to follow ethical principles in research involving living beings has been stressed in many works like (Dooly, Moore, & Vallejo, 2017). The more important ethical aspects related to this research are described below.

Ethical clearance from the University and Saudi Arabia, permission from King Abdulaziz Medical City Hospital and written consent from the focus group and survey participants were obtained as per standard procedures and guarantees. The privacy and confidentiality of the participants and their responses were addressed suitably. These participants were informed of their right to withdraw from the studies at any time without giving any reason. Both electronic and hard copy data were secured from pilferage and malware attacks on the computer. All sources used for this research and reports have been duly acknowledged. All other ethical requirements were also fully complied with.

3.8 Summary

This chapter described the principles and procedures of the modelling techniques used in this research for e-health solutions of personalised diabetes management in King Abdulaziz Medical City, Jeddah. Literature was sufficiently consulted to provide a valid basis for the steps adopted in this research. Moreover, the formulation of the research methodology to answer the research questions and achieve the research's goal was discussed in this chapter. It described the research methodology, research philosophy, research approach, research design, and methodologies chosen for this study, along with justifications. The research design and mixed-methods methodology utilised for focus group and quantitative data collecting and analysis as well as the motivations for employing mixed methods were also discussed in this chapter.

Chapter 4 – Results: Quantitative

4.1 Introduction

Many healthcare projects and innovations have been introduced in previous years to accomplish universal healthcare analysis and enhance the value of healthcare provided. These healthcare advances are inextricably linked to several quickly changing social and environmental aspects, such as population growth, the cost of living and lifestyles. Although these healthcare projects and innovations promise to improve healthcare in both quality and efficiency, a huge number of health projects have failed or are on the verge of failing.

In this chapter, a quantitative study is done to assess customer satisfaction with healthcare products and services in Saudi Arabia and to evaluate the proposed research methodology for the larger aim. This chapter quantitatively evaluates the proposed healthcare goals and objectives among healthcare users in Saudi Arabia, as quantitative research is extremely valuable in quantifying the real issue by creating study data that can be transformed into usable facts or numerical data.

A quantitative method is suitable for analysing big data sets and quantifying participants' attitudes, thoughts, behaviours, and other study characteristics. As a result, quantitative analysis allows us to assess the proposed healthcare goals and objectives for a broad population, enhancing the model's dependability and applicability.

This chapter also includes an extension of the data gathering as well as an assessment of the suggested framework's reliability and validity. Furthermore, quantitative data analysis is necessary to evaluate the framework, which includes the factors that influence an individual's acceptance of healthcare services and, in the case of Saudi Arabia, how alignment between healthcare agencies and information systems aids in the improvement of diabetes-related healthcare service quality.

The goal of the survey conducted in this research is to determine the validity of healthcare goals and objectives and to test the suggested healthcare goals in Saudi Arabia's healthcare sector. For questions involving descriptive study data, for example, study participants' individual information and backgrounds, nominal variables SPSS software were employed.

4.2 Data Analysis Methodology

The aims of this data analysis are:

1. To provide a demographic and diabetes status profile of the sample.
2. To establish if the experience of and attitude towards the e-health-based self-management system for diabetes scales used in the survey can be considered to be internally consistent.
3. To address the following:
   a. To gain an understanding of the status of the outpatients' treatment for diabetes and the patients' experience of and attitude about e-health based self-management system for diabetes; and
   b. To establish if there is any significant association between the patient experience and attitude about e-health based self-management system for diabetes AND the demographics of the patients and their diabetes status.

The latest version of SPSS statistical software was used for quantitative analysis. In a range of statistical analysis applications, the SPSS software has been proven to be dependable. For all questions with a categorical response, frequency distributions (counts and percentages) were tallied (nominal or ordinal). The trends were presented based on whether the majority of the responses (more than 50 percent of the participants) were situated. Where appropriate, the skewness of the distributions (e.g., where the greatest frequencies were situated) was noted. For questions with a continuous response, summary statistics (e.g., means or standard deviations (SD)) have been presented depending on whether a variable is regularly distributed.

The data were tested using Cronbach's alpha as a method to assure internal consistency. The set of items was internally consistent in gauging the purpose of each element and had an alpha value of 0.7 or higher (Reynaldo & Santos, 1999). The survey includes two scales, one for experience and one for attitude with an e-health-based diabetes self-management system. The average of the individual items from each of the two scales used in the survey was used to construct variable scores. In the statistical analysis results section, the conceptual operational descriptions of the scores are supplied.

The main technique used for addressing the aims of the data analysis is Spearman's correlation analysis. A Spearman's correlation analysis is a useful technique to test for association between a pair of variables (when some variables might be ordinal or not normally distributed) (Katz, 2011; Tabachnick & Fidell, 2007). Dummy variables were created from the demographic and other questions to allow for running a correlation analysis. A 0.05 level of significance was used as the criteria for statistical significance. The results obtained from the analyses of data are described in the subsequent sections.

4.3 Preliminary Stage of Data Analysis

The initial phase of study data assessment entailed selecting the most appropriate data analysis approach as well as research data assessment and pre-enciphering the research replies to guarantee that the data were clean (Bauer et al., 2021; Spackman et al., 2021). When the proposed research data were obtained from the online website Qualtrics and stored in Excel format, a numeric range was assigned to every variable in the research questionnaire for the pre-screening procedure, and the newest version (27) of the statistical analysis tool and SPSS software was used. The information was then imported to SPSS for additional evaluation (Bauer et al., 2021; Spackman, et al., 2021). All through the screening and cleaning stages, the research data were examined for normal data distribution, data correctness, outlier identification and missing values from the collected data.

Outliers in the data, their significance, interpretations and methods used to deal with them in this study.

Outliers in research data are described as replies that differ considerably in some respects. This is an important influencing aspect since the results of the study analysis could lead to unfairness in the supposed data variables in healthcare, as outliers can cause unfairness in the arithmetical mean value and raise the standard deviation (Bauer et al., 2021; Spackman et al., 2021). When assuming key assumptions from the adaption of a statistical regression test, the study data could have been influenced by outliers in the case of data normalcy. As a result, the research data were prepared and tested using a process known as Z scores, which combines a histogram and a box-plot graph to identify and expose outliers (Bauer et al., 2021; Spackman et al., 2021).

Furthermore, two portions of the research questionnaire are expected to classify outliers based on the circulation of the components as well as the inability to discover missing data and inaccurate data storage (Bauer et al., 2021; Spackman et al., 2021). Only by changing the score, changing the data or eliminating the instances can the outlier dilemma be solved, and in this research, box-plot graphs and histogram graphs were employed to chart the research data to detect the outliers more readily. Agreeing with Bauer et al. (2021) and Spackman et al. (2021), an arithmetical method that includes assessing the standard deviation from the arithmetical mean value has been widely used and was selected for this study.

The research data was altered to spread the outliers discovered in this study, allowing the approval of healthcare services to be recorded. While applying the variable assessment examination result, the arithmetical mean value included the average value of the high level of all related loaded sub-factors of any variable. Despite the data conversion, outliers were expected in this research.

4.4 Results on the Diabetic Profile of Saudi Patients

4.4.1 Sample Participant Profile

Demographics

The sample consisted of 210 participants. The demographic profile of the sample is summarised in Tables 4.1 to 4.4 and Figure 4.1.

Table 4.1: Gender distribution of participants

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Male	86	41.0	41.5	41.5
	Female	121	57.6	58.5	100.0
	Total	207	98.6	100.0	
Missing	System	3	1.4		
Total		210	100.0		

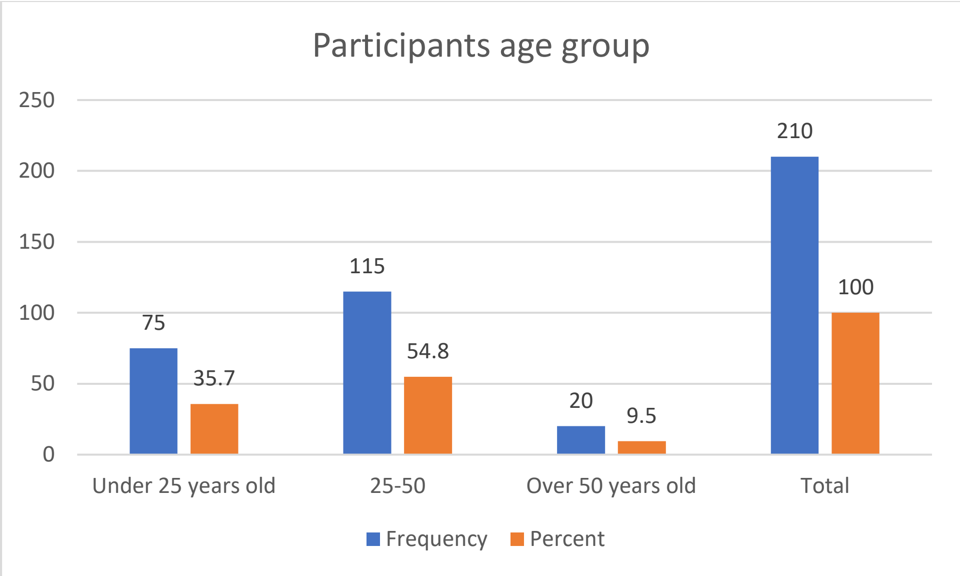

Figure 4.1: Participants’ age group

Table 4.2: Educational qualifications of participants

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Secondary or less	72	34.3	34.4	34.4
	Bachelor’s degree or diploma	120	57.1	57.4	91.9
	Postgraduate studies and above	15	7.1	7.2	99.0
	Special training	2	1.0	1.0	100.0
	Total	209	99.5	100.0	
Missing	System	1	.5		
Total		210	100.0		

Table 4.3: Employment status of participants

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Unemployed	100	47.6	50.5	50.5
	Personal business	15	7.1	7.6	58.1
	Working in a private	25	11.9	12.6	70.7

	company				
	Working for a government company	8	3.8	4.0	74.7
	Government employee	50	23.8	25.3	100.0
	Total	198	94.3	100.0	
Missing	System	12	5.7		
Total		210	100.0		

Table 4.4: Monthly income level of participants

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	8,000 Saudi riyals or less	106	50.5	59.9	59.9
	From 8,000 to 15,000 Saudi riyals	52	24.8	29.4	89.3
	More than 15,000 Saudi riyals	19	9.0	10.7	100.0
	Total	177	84.3	100.0	
Missing	System	33	15.7		
Total		210	100.0		

The above data shows that a majority of the respondents were females (n = 121, 58.5 percent), in the age range of 25–50 years (n = 115, 54.8 percent), had completed a bachelor's degree or a diploma (n = 120, 57.4 percent), were unemployed (n = 100, 50.5 percent), and had a monthly income level of less than 8,000 Saudi riyals (n = 106, 59.9 percent).

Correlations of demographic variables of patients with e-health variables might lead to the predictability of acceptance or resistance to use e-heath systems for self-management of the disease. They also help profiling of those who are likely to get diabetes. The extent of reduction in diabetes prevalence according to demographic variables can lead to the estimation of the economic impact of reducing the prevalence to targeted levels. These effects have been demonstrated in the latter sections of this chapter.

4.4.2 Diabetes Status

The diabetes status profile of the sample is summarised in Tables 4.5 and 4.6.

Table 4.5: How long have you been diabetic?

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	A year or less	25	11.9	12.0	12.0
	From one to five years	37	17.6	17.8	29.8
	Five years or more	146	69.5	70.2	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

Table 4.6: Are you a Type 1 or Type 2 diabetes patient?

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Type 1 (insulin-dependent)	158	75.2	77.1	77.1
	Type 2 (blood sugar level)	47	22.4	22.9	100.0
	Total	205	97.6	100.0	
Missing	System	5	2.4		
Total		210	100.0		

As shown in the data given in Tables 4.5 and 4.6, most of the people in the sample have been diabetic for more than 5 years (n = 146, 70.2 percent). Most of the people had Type 1 diabetes (n = 158, 77.1 percent).

4.4.3 Outpatient Treatment Profile

The responses of the participants to many outpatient treatment aspects are shown in Tables 4.7 to 4.24 and Figures 4.2 and 4.3.

Table 4.7: Outpatient treatment – Has a medical treatment been prescribed for diabetes?

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	199	94.8	96.1	96.1
	No	8	3.8	3.9	100.0
	Total	207	98.6	100.0	
Missing	System	3	1.4		
Total		210	100.0		

Medication was prescribed for about 95% of the participants. For the remaining eight patients, it might not have been necessary, as their blood glucose levels would not have been beyond the limits of diabetes diagnosis. Integrating this with Table 4.6, out of 205/207 diabetes patients diagnosed withT1D or T2D, eight were not prescribed any medicine. Another possible explanation is that the eight participants (who had T1D or T2D) had comorbidities for which medicines have been prescribed which might affect the efficacy of any medicine for glucose control.

Table 4.8: Outpatient treatment – I follow the prescribed medications carefully

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	183	87.1	88.0	88.0
	No	25	11.9	12.0	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

Although medication has been prescribed for about 96 percent of the participants (n = 199) (Table 4.7), only 88 percent (n = 183) (Table 4.8) followed the prescribed medications. Thus, 16 participants were not following the prescribed medications.

Tables 4.5 to 4.8 were related to one of the three interventions (medicine, diet, and physical activity) to manage diabetes. Taken together, almost 205-207 participants were diabetic. Out of 210, 158 (75%) had TID, signifying the requirement for insulin injections. If projected to the total diabetic population, the country's insulin requirement will be very large. If diabetes is left uncontrolled, a need may arise for import of large quantities of insulin. Since most of the participants were TID, the prescriptions given to the 199 participants in Table 4.7 could be insulin injections. As shown in Table 4.8, about 12% of the participants did not follow medication prescribed to them. Not following medication could be due to ignorance about the disease and what the medication will do. Here, e-health with self-management can help, as the system has provisions to provide the required knowledge to the patients. Thus, the findings from these tables highlight the need for a e-health system for self-management of diabetes.

Table 4.9: Outpatient treatment – Has a diet been prescribed to control diabetes?

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	137	65.2	65.9	65.9
	No	71	33.8	34.1	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

Table 4.10: Outpatient treatment – I follow the prescribed diet carefully

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	62	29.5	29.8	29.8
	No	146	69.5	70.2	100.0
	Total	208	99.0	100.0	

Missing	System	2	1.0
Total		210	100.0

Although diet has been prescribed to about 66 percent (n = 137) of participants (Table 4.9), only about 30 percent (n = 62) followed the prescribed diet (Table 4.10). Thus, more than half of the participants were not following the prescribed diet. This observation is more serious than that on medication, as the number of non-compliant patients is more than double of those complying with diet prescriptions. Here too, the importance of e-health systems is obvious.

Table 4.11: Outpatient treatment – I was asked to exercise daily to keep my diabetes under control

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	172	81.9	82.7	82.7
	No	36	17.1	17.3	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

Table 4.12: Outpatient treatment – I follow the daily exercise program exactly

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	47	22.4	22.5	22.5
	No	162	77.1	77.5	100.0
	Total	209	99.5	100.0	
Missing	System	1	.5		
Total		210	100.0		

Out of 172 (83 percent) participants, only 47 (22.5 percent) followed the prescribed daily exercise program (Tables 4.11 and 4.12) and about 78 percent of them were not doing the prescribed exercise program. The problem of daily exercise is similar to that of diet. Hence, the significance of these findings on the need for e-health for self-management applies here also

The above tables from 4.5 to 4.12 demonstrated the compliance deficits among many diabetic patients in following the prescriptions on the three important interventions- medication, diet, and exercise and thus justify the implementation of e-health systems for self-management by patients to inform them about the disease and the importance of the three interventions, so that the compliance levels can be increased. Now we examine what is happening with respect to the few e-health and self-management programmes already in place.

Table 4.13: Outpatient treatment – After visiting the primary outpatient clinic in the hospital and after consulting them, I am now in my home under self-care.

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	182	86.7	87.9	87.9
	No	25	11.9	12.1	100.0
	Total	207	98.6	100.0	
Missing	System	3	1.4		
Total		210	100.0		

From Table 4.13, about 88 percent of participants (n = 182) said that they were under self-care in their homes after visiting the primary hospital. The rest (n = 25, 12 percent) either did not visit the primary care hospital or were not under self-care in their homes or both.

Table 4.14: Outpatient treatment – Does the hospital have an e-health self-care management system for diabetics?

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	72	34.3	34.4	34.4

	No	137	65.2	65.6	100.0
	Total	209	99.5	100.0	
Missing	System	1	.5		
Total		210	100.0		

The data in Table 4.14 shows that the existence of an e-health self-care management system in their hospitals was reported by only 72 participants (34.4 percent). This may mean that out of 182 participants who visited a primary care hospital before self-care at home (Table 4.14), 110 participants were not under an e-health-based self-care system.

Table 4.15: Outpatient treatment – I am a registered user of the hospital e-health system.

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	88	41.9	42.1	42.1
	No	121	57.6	57.9	100.0
	Total	209	99.5	100.0	
Missing	System	1	.5		
Total		210	100.0		

About 42 percent (n = 88) said that they were registered users of an e-health system. In Table 4.14, 72 said e-health systems existed in their hospitals. That may not mean that only they were using hospital e-health systems. This extra 16 people might also be using the e-health systems already existing in the same hospitals.

The results of 4.13 to 4.15 show that most patients are under self-care, but not necessarily under a e-health programme, as only a few hospitals have implemented it. This shows the need to have an effective e-health programme, implemented in most hospitals facilitating self-care by their diabetic patients. This is the core theme of this research.

Table 4.16: Outpatient treatment – My self-care program contains regular blood glucose monitoring from home

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	121	57.6	58.7	58.7
	No	85	40.5	41.3	100.0
	Total	206	98.1	100.0	
Missing	System	4	1.9		
Total		210	100.0		

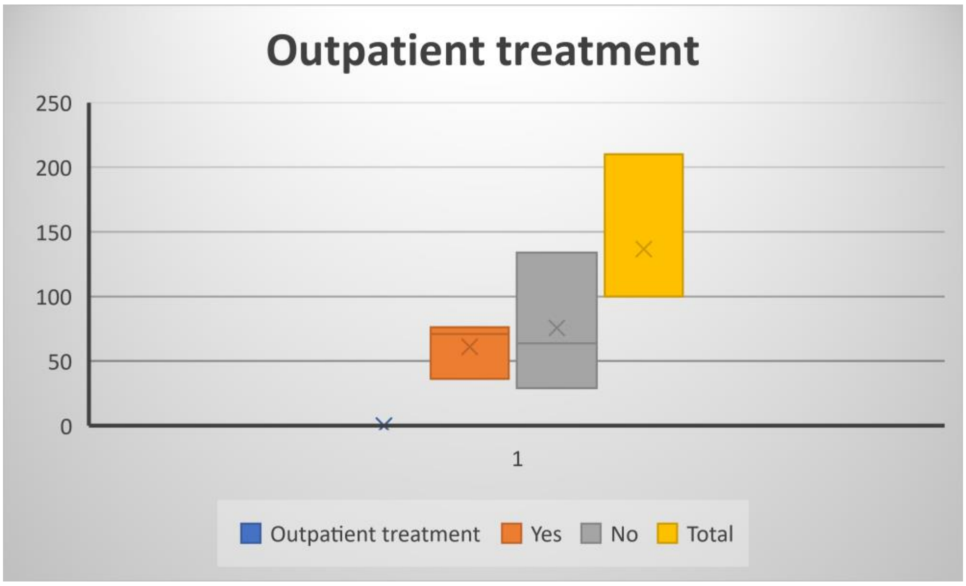

Figure 4.2: Outpatient treatment – I monitor blood glucose at home regularly as prescribed.

Table 4.17: Outpatient treatment – I reported to the hospital blood glucose levels through the e-health system

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	49	23.3	23.6	23.6
	No	159	75.7	76.4	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

Although only 121 participants had (about 58 percent) been prescribed regular monitoring of blood glucose, 149 participants (about 71 percent) were monitoring it. So, 28 people were monitoring blood glucose on their own. However, only 49 (about 24 percent) of them reported their blood glucose values through the e-healthcare system (Tables 4.16 and 4.17 and Figure 4.2). It is not clear whether others did not report because the blood glucose levels were within the desirable limits.

Table 4.18: Outpatient treatment – My self-care program includes insulin injections as prescribed by my doctor.

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	134	63.8	65.0	65.0
	No	72	34.3	35.0	100.0
	Total	206	98.1	100.0	
Missing	System	4	1.9		
Total		210	100.0		

Table 4.19: Outpatient treatment – I inject insulin regularly as prescribed.

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	156	74.3	75.4	75.4
	No	51	24.3	24.6	100.0
	Total	207	98.6	100.0	
Missing	System	3	1.4		
Total		210	100.0		

Table 4.20: Outpatient treatment – I reported details of insulin injections through the e-health system.

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	44	21.0	21.5	21.5

	No	161	76.7	78.5	100.0
	Total	205	97.6	100.0	
Missing	System	5	2.4		
Total		210	100.0		

Data presented in Tables 4.18 and 4.19 show that insulin injections were prescribed for 134 participants (about 65 percent) but regular insulin injections as prescribed were taken by 156 (about 75 percent), but only 44 (21.5 percent) of them reported the details through e-health systems. Others either were not under e-health system or deliberately did not report through e-health systems.

Table 4.21: Outpatient treatment – My self-care program contains a daily diet-regulating program.

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	89	42.4	42.8	42.8
	No	119	56.7	57.2	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

Table 4.22: Outpatient treatment – I follow the regular diet regimen regularly as prescribed.

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	60	28.6	29.0	29.0
	No	147	70.0	71.0	100.0
	Total	207	98.6	100.0	
Missing	System	3	1.4		
Total		210	100.0		

From the data in Tables 4.21 and 4.22, it can be noted that despite regular diet regimens having been prescribed for 89 (about 43 percent) of participants, only 60 (about 29 percent) of them followed the prescribed diet regimen. But most of them were out of diet regimens, with 119 not prescribed and 147 not following it.

Table 4.23: Outpatient treatment – My self-care program contains a daily workout program

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	69	32.9	33.2	33.2
	No	139	66.2	66.8	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

Table 4.24: Outpatient treatment – I exercise regularly as scheduled

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	Yes	53	25.2	25.5	25.5
	No	155	73.8	74.5	100.0
	Total	208	99.0	100.0	
Missing	System	2	1.0		
Total		210	100.0		

The data presented in Tables 4.23 and 4.24 show that daily workout programs were prescribed for 69 (about 33 percent) of the participants. But only 53 (25.5 percent) of them followed the prescribed exercise plan.

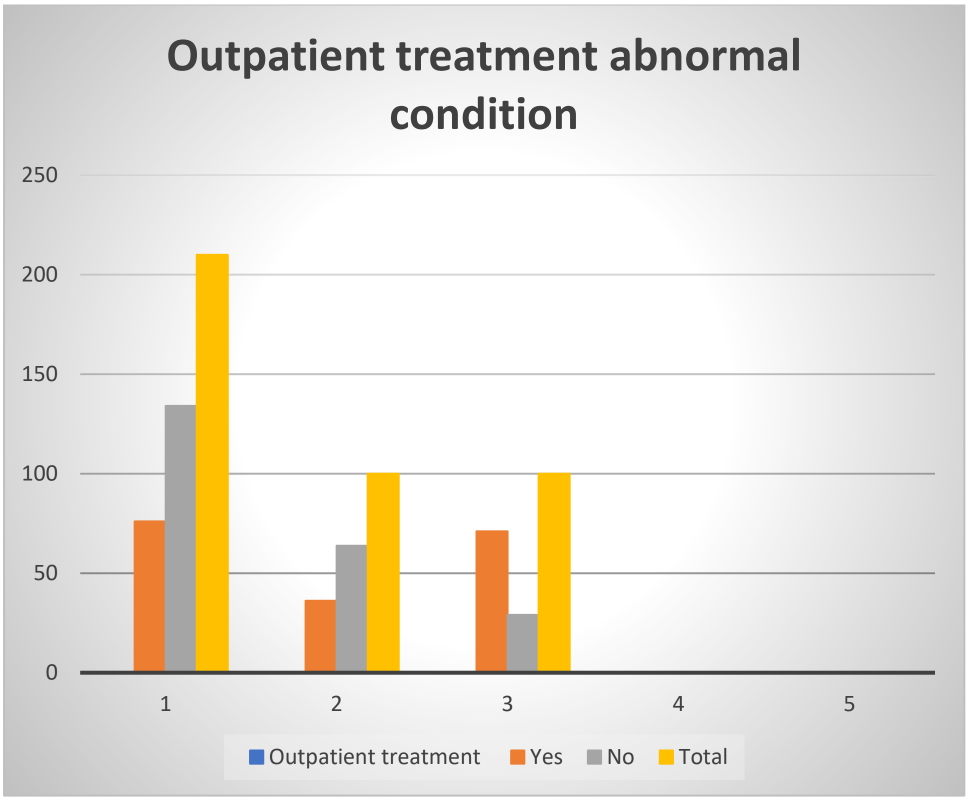

Figure 4.3: Outpatient treatment – I informed the hospital when any abnormal condition occurred in my health through the hospital's e-health system.

As shown in Figure 4.3, only 76 (about 36 percent) of the people reported any abnormal condition in their health through the e-health care system of the hospital.

Overall, low compliance levels and low levels of reporting are the main problems in the case of the sample diabetic patients. So, improving these two aspects needs to be a design requirement of the proposed e-healthcare model for the self-management of diabetes in Saudi Arabia.

4.4.4 Internal Consistency

The internal consistency analysis of the experience and attitude with an e-health-based self-management system for diabetes scales is presented in Table 4.25. The reliability coefficients (Cronbach's alpha) for the two scales were greater than 0.7 and hence acceptable. Therefore, the scales can be considered internally consistent to be used in subsequent analysis.

Table 4.25: Internal consistency

Scale	Number of items (N)	Cronbach's alpha
Experience with e-health system scale	5	0.717
Attitude to e-health system scale	5	0.819

4.4.5 Variable Scoring

Two variable scores were created using the experience and attitude of an e-health-based self-management system for diabetes scales. The conceptual and operational definitions of these scores are given in Table 4.26 below. Variable scoring is done for further analysis to find out effects, relationships, and predictive modelling. These are required for determining the modelling requirements in this study.

Table 4.26: Variable scoring

Variable	Conceptual definition	Operational definition		
		Number of items	Computation	Interpretation of scores
Experience with e-health system score	Experience with e-health system score	5	Average rating of 1 to 5 scores for all items	1 = Low levels 5 = High levels
Attitude about e-health system score	Attitude about e-health system score	5	Average rating of 1 to 5 scores for all items	1 = Low levels 5 = High levels

4.4.6 Patient Experience of and Attitude towards E-health Based Self-management Systems for Diabetes

The summary statistics of the experience of and attitude towards e-health-based self-management systems for diabetes scores are shown in Table 4.27.

Table 4.27: Summary statistics for the experience and attitude about e-health based self-management system for diabetes scores.

	N	Min.	Max.	Mean	SD
Experience with e-health system score	210	1.00	5.00	3.38	0.69
Attitude about e-health system score	208	1.40	5.00	3.66	0.73

Since the mean scores for both the variable scores are greater than 3 (the mid-point of a 1 to 5 Likert scale), it is safe to say that the experience and attitude of the patients towards the e-health system for self-management of diabetes was favourable or above average. Both experience and attitude will be considered for e-health modelling.

4.4.7 Correlation Analysis

The correlations between the experience and attitude toward e-health-based self-management systems for diabetes scores and the demographics of the patients are shown in Table 4.28.

Table 4.28: Correlation analysis

	Experience with e-health system score	Attitude about e-health system score
Attitude about e-health system score	0.555**	-
Male	-0.053	-0.113
Female	0.053	0.113
Age – Under 25 years old	-0.028	-0.007
Age – 25–50 years old	0.077	-0.031
Age – Over 50 years old	-0.085	0.065
Education – Secondary or less	-0.010	0.040
Education – bachelor’s degree or diploma	-0.100	-0.095
Education – Postgraduate studies and above	0.160*	0.081
Education – Special training	0.134	0.072

	Experience with e-health system score	Attitude about e-health system score
Employment – Unemployed	-0.084	-0.014
Employment - Personal business	0.055	0.039
Employment – Working in a private company	0.013	-0.017
Employment – Working for a government company	.0.120	0.075
Employment – Government employee	-0.001	-0.028
Income – 8,000 Saudi riyals or less	-0.006	0.166*
Income –From 8,000 to 15,000 Saudi riyals	0.000	-0.133
Income – More than 15,000 Saudi riyals	0.010	-0.067
Diabetes duration – A year or less	0.136	0.037
Diabetes duration – From one to five years	0.010	-0.038
Diabetes duration – Five years or more	-0.105	0.005
Diabetes type – Type 1 (insulin-dependent)	0.023	-0.013
Diabetes type – Type 2 (blood sugar level)	-0.023	0.013

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The notable findings from the analysis are as follows:

- There is a positive and significant correlation between the experience with e-health system scores and the attitude about e-health system score.
- There is a positive and significant correlation between the experience with e-health system score and the participant having higher education (postgraduate or more); and
- There is a positive and significant correlation between the attitude about the e-health system score and the participant having a low income (8,000 Saudi riyals or less).

4.4.8 Regression Analysis

A model with attitude about e-health system score as the dependent variable and gender, age, education, employment, income, diabetes duration and diabetes type as the independent variables found that having a monthly income of 8,000 Saudi riyals or less predicted a significant proportion of variables in the dependent variable $R^2 = .034$, $F(1, 166) = 5.849$, $p = .017$ (Table 4.29).

Table 4.29: Regression model

Model		Unstandardized coefficients		Standardized coefficients		
		B	Std. error	Beta	t	Sig.
1	(Constant)	3.535	.083		42.671	.000
	Income – 8,000 Saudi riyals or less	.260	.107	.184	2.418	.017

a. Dependent Variable: Attitude about e-health system score

A model with experience with e-health system score as the dependent variable and gender, age, education, employment, income, diabetes duration and diabetes type as the independent variables did not find any significant predictors.

The predictive equation therefore becomes.

Attitude about e-heath system = 3.535+ 0.260 * Income 8,000 SAR or less.

This means attitude towards the e-health system is more positive among low-income people in Saudi Arabia. This will be a factor to consider in modelling and impact estimations.

4.5 Analysis of Survey Data on Interventions

Results of the survey of 100 participants on the effect of interventions on blood sugar levels are presented below.

4.5.1 Sample Profile

The sample consists of a total, of N = 100 participants. Tables 4.30 and 4.31 provide the profile of the participants.

Table 4.30: Frequency by gender

	N	Percentage
Female	67	67.0
Male	33	33.0

Table 4.31: Frequency by age group

Age	N	Percentage
Less than 25 years old	58	58.0
25 to 50 years old	33	33.0
50+ years old	9	9.0

Most of the participants studied were female (n = 67, 67 percent), and the remainder were male (n = 33, 33 percent). Most of the participants were less than 25 years old (n = 58, 58.0 percent), then 25 to 50 years old (n = 33, 33.0 percent), and a few participants were 50+ years old (n = 9, 9.0 percent).

Table 4.32 provides the nature of interventions for the control of diabetics in the participants.

Table 4.32: Frequency by nature of intervention

	N	Percentage
Diet control	42	42.0
Exercise	22	22.0
Medication changes	36	36.0

The participants were provided with three types of treatments as part of the nature of intervention. As shown in Table 4.32 above, most of the participants were on diet control (n = 42, 42.0 percent), a lower number of participants were on medication changes (n = 36, 36.0 percent), and the remainder on exercise (n = 22, 22.0 percent). Thus, diet control seems to be the major intervention prescribed for the control of diabetes.

In Table 4.33, data on duration and blood glucose status before and after interventions are given.

Table 4.33: Descriptive Statistics

	Mean	Std. Deviation	Variance
Duration of diabetes (years)	9.68	8.12	65.95
Average blood glucose levels before intervention (mmol/L)	14.27	6.11	37.29
Average blood glucose levels after intervention (mmol/L)	7.93	2.32	5.36
The difference in average blood sugar level before and after (mmol/L)	6.33	5.48	30.01

On average, the participants had been diabetic for 9.68 years with a standard deviation of 8.1207 years (0.5–54 years). Average blood glucose levels before intervention were 14.267 mmol/L with a standard deviation of 6.1069 mmol/L (5.3–33.3 mmol/L). Average blood glucose levels after the intervention were 7.933 mmol/L with a standard deviation of 2.316 mmol/ L (4.7–19.4 mmol/L). Thus, the reduction in average blood sugar level over all the interventions was an average of 6.334 mmol/L with a standard deviation of 5.478 mmol/L, although in the actual data there was one case each for no change and increase in blood glucose levels after the intervention.

4.5.2 Multivariate Analysis

The main multivariate analysis technique used for addressing the aims of data analysis with multiple variables or relationships is multiple linear regression analysis. Multiple linear regression modelling is a valid technique that models the strength and direction of the relationship between one or more independent variables and a dependent variable (Katz, 2011; Tabachnick & Fidell, 2007).

Table 4.34: Summary statistics for nature of intervention by difference in average blood sugar level

Nature of intervention				Statistic
The difference in average blood sugar level before and after (mmol/L)	Diet	Mean		6.3167
		95% Confidence interval for mean	Lower bound	4.5374
			Upper bound	8.0959
		5% trimmed mean		5.8955
		Median		5.2500
		Variance		32.600

	Std. deviation		5.70964
	Minimum		-3.30
	Maximum		23.00
	Range		26.30
	Interquartile range		6.10
Exercise	Mean		4.2000
	95% Confidence interval for mean	Lower bound	2.4785
		Upper bound	5.9215
	5% Trimmed mean		3.8500
	Median		2.9000
	Variance		15.075
	Std. deviation		3.88268
	Minimum		0.30
	Maximum		14.40
	Range		14.10
	Interquartile range		4.13
Medication	Mean		7.6583
	95% Confidence interval for mean	Lower bound	5.7154
		Upper bound	9.6013
	5% Trimmed mean		7.1710
	Median		5.6000
	Variance		32.975
	Std. deviation		5.74239
	Minimum		1.20
	Maximum		24.40
	Range		23.20
	Interquartile range		6.68

The impacts of the three different natures of intervention – that is diet, exercise, and medication – were studied or compared to ascertain the impact on the difference in average blood sugar level before and after. An extract of the Table 4.34 giving only the relevant data is given in Table 4.35.

Table 4.35: Reduction in blood sugar levels achieved through the three interventions.

Intervention	Mean reduction (mmol/L)	Std deviation
Diet	6.3167	5.7096
Exercise	4.2000	3.8827
Medication	7.6583	5.7424

The highest reduction was achieved by medication, followed by diet and then by exercise. All mean values had large variations as indicated by the high standard deviation values. This result sets priorities for different interventions in the e-heath model for self-care management.

In Table 4.36. the data on the reduction in blood glucose level with age as the affecting variable is given.

Table 4.36: Summary statistics for age by difference in average blood sugar level

Age				Statistic
The difference in average blood sugar level before and after (mmol/L)	25 to 50	Mean		6.1030
		95% Confidence interval for mean	Lower bound	4.1993
			Upper bound	8.0067
		5% Trimmed mean		5.8571
		Median		4.4000
		Variance		28.825
		Std. deviation		5.36886
		Minimum		-3.30
		Maximum		19.50
		Range		22.80
		Interquartile range		7.30
	50+	Mean		3.4444
		95% Confidence interval for mean	Lower bound	0.9107
			Upper bound	5.9782
		5% Trimmed mean		3.1772
		Median		2.2000
		Variance		10.865
		Std. deviation		3.29625
		Minimum		0.60
		Maximum		11.10
		Range		10.50

Age				Statistic
		Interquartile range		3.95
	Less than 25	Mean		6.9138
		95% Confidence interval for mean	Lower bound	5.4098
			Upper bound	8.4178
		5% Trimmed mean		6.4128
		Median		5.5000
		Variance		32.718
		Std. deviation		5.71997
		Minimum		-1.40
		Maximum		24.40
		Range		25.80
		Interquartile range		5.60

As was done in the case of interventions, a similar summarisation of relevant data is presented in Table 4.37.

Table 4.37: Reduction in blood sugar levels according to the age of the participant

Age group	Mean reduction in blood glucose level (mmol/L)	Standard deviation
Less than 25 years	6.9138	5.7200
25–50 years	6.1030	5.3689
Over 50 years	3.444	3.2962

The mean values in Table 4.37 shows that the effect of age on the achievable reduction in blood sugar levels occurs mainly in participants younger than 50 years. Achievable reductions in the blood sugar levels of patients over 50 years of age decreases drastically, demonstrating the difficulty in controlling diabetes among older people. Thus, there is a need for a separate focus on older diabetic patients in the e-health system model.

Table 4.38: Summary statistics for gender by the difference in average blood sugar level

Gender (male/female)				Statistic
The difference in average blood sugar level before and after (mmol/L)	Female	Mean		6.5269
		95% Confidence	Lower bound	5.1181

	interval for mean	Upper bound	7.9356
	5% Trimmed mean		6.0724
	Median		5.5000
	Variance		33.355
	Std. deviation		5.77538
	Minimum		-3.30
	Maximum		24.40
	Range		27.70
	Interquartile range		6.50
Male	Mean		5.9424
	95% Confidence interval for mean	Lower bound	4.2125
		Upper bound	7.6723
	5% Trimmed mean		5.5471
	Median		5.0000
	Variance		23.802
	Std. deviation		4.87872
	Minimum		-1.40
	Maximum		23.00
	Range		24.40
	Interquartile range		5.95

As in the case of the earlier two cases, the relevant data extracted from Table 4.38 are presented in Table 4.39.

Table 4.39: Reduction in blood glucose level by gender of the patient

Gender	Mean reduction in blood glucose level (mmol/L)	Standard deviation
Female	6.5269	5.7754
Male	5.9424	4.8787

The data in Table 4.39 indicates that female participants have a better chance of a high reduction in blood sugar levels and thus a return to normal health compared to male participants. This possibility needs to be built into the e-health system models.

Table 4.40: Regression

	Unstandardized coefficients		Standardized coefficients		
Model	B	Std. error	Beta	t	Sig.
(Constant)	6.936	.610		11.375	<.001
Dummy Exercise	-2.736	1.300	-.208	-2.104	.038

A stepwise regression model was developed with difference in average blood sugar level – before and after intervention (mmol/L) as the dependent variable and gender (dummy variables), age (dummy variables), duration of diabetes and nature of the intervention (dummy variables) as independent variables. The results of the analysis indicate that the exercise (p = .038) as an intervention accounted for a significant proportion of the dependent variable, R2 = .043, F (1, 98) = 4.429, p = .038. Thus, the predictive equation becomes-

Reduction in blood sugar level = 6.936 – 2.736 * Exercise.

This equation shows exercise alone can reduce blood sugar levels in diabetic patients. However, this result leads to some confusion. According to the earlier results, the highest reduction of blood sugar occurred following the nature of intervention of medication, followed by diet and then exercise. In summary, it can only be said that equal attention is required to all these three interventions for the effective reduction of blood sugar levels to a healthy level and to maintain this over the long term.

4.6. General direction of the findings

The demographic variables showed that most of the respondents were females, in the age range of 25–50 years, had completed a bachelor's degree or a diploma, were unemployed, and had a monthly income level of less than 8,000 Saudi riyals. The possibility of adopting modern lifestyles by unemployed or low-income diabetic patients is low, as they do not have enough money to indulge in such practices. This is especially true if they are women. Low-income people in search of jobs may even accept hard manual jobs. So, low levels of physical activity may not be the cause for diabetes among them. Other reasons need to be explored.

Survey results showed that overall, low compliance levels and low levels of reporting are the main problems in the case of the sample diabetic patients. So, improving these two aspects needs to be a design requirement of the proposed e-healthcare model for the self-management of diabetes in Saudi Arabia. The low level of compliance could be due to the paucity of income to buy medicines or food suitable for dieting. Unemployment and low-income levels drive them to search for better jobs. Thus, they may not have time for separate exercise regimen.

Experience and attitude towards e-health for diabetes self-management were positive. This is a good sign for implementation of e-health for self-management of diabetes. The average blood sugar level decreased from 14.27 before intervention to 7.93 mmol/L after intervention. Mean sugar level reductions were 7.6583 mmol/L for medication, 6.3167 mmol/L for diet control and 4.200 mmol/L for exercise. The reduction was higher at younger ages and for females. Regression analysis showed that exercise alone can reduce blood sugar substantially. This is contrary to the finding that the reduction in blood sugar was lowest for exercise compared to medication and diet. These reductions by the three interventions can be used to incorporate the interventions in e-health system based on the patient characteristics. The economic impact of these significant reduction is tremendous.

4.7. Summary

This chapter describes the results of the quantitative analysis which demonstrate the effects of the selected healthcare variables in the context of the implementation of the health sector in Saudi Arabia. The chapter focuses on healthcare users' experience and attitude towards the service supplied in the Kingdom of Saudi Arabia. This chapter also discusses a simple assessment to verify the reliability of the research data by identifying outliers of normal data distribution statements and missing values.

Chapter 5 – Results: Focus Group

5.1 Introduction

This chapter presents the focus group part of the thesis. It discusses the rationale for using semi-structured conversations among the group as well as the sampling technique employed, the objective of the focus group, empirical data collecting, qualitative data processing and the study's empirical findings. By confirming the alignment factors to enhance the e-health environment and improve the services provided to the public, this phase of the study answers the first research question (RQ1: What is the current situation of e-health in Saudi Arabia?). A full list of the focus group questions is provided in Appendix B. Some examples of questions are: "Could each diabetic patient please describe his/her experience in managing his/her diabetes at home. Was there any difficulty?"; "Let us assume, the patient reported high sugar readings thrice during the last three-month monitoring"; and "How to improve e-health services in Saudi Arabia?" The methodology used to conduct the focus group, the collection of data and the analysis were described in Chapter 3, which outlines the methodology of the thesis.

As was explained in Chapter 3, the qualitative data from the focus group was analysed using the thematic analysis proposed by Braun et al. (2014). The objective of the focus group was to provide explanatory support for identifying modelling requirements from a stakeholder point of view. Hence, the possibility of identifying any modelling requirement was used as the benchmark to identify themes and subthemes in this analysis. In this focus group, four each of diabetes patients, doctors and nurses, IT specialists and close relatives and friends participated. Questions were designed to be answered by different groups of stakeholders. A detailed methodology is given in Chapter 3.

5.2 Thematic Analysis

The following steps were used manually for this thematic analysis following the method described by Braun et al. (2014):

1. Familiarising yourself with the data and identifying items of potential interest.
2. Generating initial codes.
3. Searching for themes.
4. Reviewing potential themes.

5. Defining and naming themes.
6. Producing the report.

The results of these steps are given below. The test of removing the responses to examine the correctness of codes was done as prescribed by Braun et al. (2014).

The themes were related to each other as the main components of e-health systems- patients, interventions, supports and corrections when things go wrong. In the case of patients, the redisposing factors, and need for diabetes management were identified as the themes. Subthemes for patients could range from factors leading to diabetes and physiological factors requiring increasing the ability of the patients to control blood glucose levels through self-management, which is the aim of e-health. Modelling requirements arising from the subthemes were hereditary and genomic factors, and other causes leading to diabetes and uncontrolled blood sugar levels, low insulin production in the body, diet, or exercise problems. Therefore, the modelling requirement is to provide the patients with the ability to control blood sugar levels through guided self-management. Interventions to control diabetes require medication, diet and exercise for modelling. Thus, the primary interventions for blood glucose control is achieved through the modelling requirement of these three interventions. This means, regular monitoring of blood sugar levels, diet and exercise as the requirements in terms of the essential variables for a good control system to achieve the desired level of control. In an e-health system, all these require support from all stakeholders playing their respective roles. Even in a perfect system, things can go wrong due to failures on multiple fronts. All possible causes of failures become the modelling requirements. To solve these problems, apart from the individual effort, support from various quarters will be the modelling requirements. Some possible advanced and new methods for e-health for self-management include m-health, cloud storage of data, and wearable devices connected to e-heath systems. The requirements for these are exploratory in nature.

A tabulated format of the themes and subthemes was prepared from the focus group's responses and codes and themes were identified. They were corrected for language errors and expressions and rearranged in sequential order for clarity. The results of the thematic analysis are presented in Table 5.1.

Table 5.1: Results of thematic analysis

Themes	Subthemes	Variables for modelling requirements
1. Predisposing factors of diabetes	Hereditary Genomic factors Other diseases Hormonal imbalances Uncontrolled eating Eating junk food containing fats Sedentary work Lack of physical activity Eating a lot of sweet dishes	Some members have diabetes in each generation. Structural and functional aspects of genes Leading to a lack of blood sugar control. Secondary causes. Pressure-related hormones can raise glucose levels. Obesity. Blood glucose increases.
2. The need for diabetes management	Physiological factors leading to patients requiring the ability to self-manage blood glucose	Glucose in the blood raised beyond the acceptable standards. Not enough insulin production or delivery to the blood. Cells do not react appropriately to the insulin the pancreas produces. High glucose and ketone levels in urine Lower glucose supply to cells for their development. Patients require instruction and the ability to perform diabetes control self-administration.
3. Aim of diabetes control	Control of direct causes	Reduce blood sugar. Diet control. Physical activities.
4.Primary interventions	Therapies Additional	Insulin administration and other medications Planned diet and exercises or other means of

Themes	Subthemes	Variables for modelling requirements
	interventions	active life
5. Achievement of control	Variables of a good control system	Close monitoring of blood glucose and haemoglobin. Other analyses as advised. No psychological problems. Monitor menstrual cycles and pregnancy for women.
6. Supports	Clinical support Community support	The doctor advises on the medical interventions. Social support groups for diabetes patients, conduct awareness camps and training classes and provide information and advice, help in crises.
	Administration support	Ensure adequate availability of resources to the patients through easy access and affordability.
	Insurance support	Help patients in bearing the high costs of treatment.
7. When something goes wrong	Specific failures	Irregular blood glucose levels requiring closely monitored insulin administration. Non-availability of insulin and other drugs at critical times. Failure in addressing other complexities or comorbidities like cardiac or renal problems as indicated by higher levels of albumin or proteins in urine. Side effects of drugs. Diabetic neuropathy harms the nerves, influences warmth, cold, and agony, increasingly vulnerable to injury not noticeable and these wounds develop into genuine complications.
	Psychological problems	Feeling pushed, desolate, incensed or worried, causing mental strain. Stress can raise blood glucose levels. Other complications like cerebral problems

Themes	Subthemes	Variables for modelling requirements
	System failures Failure of any one or more supports	and stroke. Sudden catastrophic developments can jeopardise the entire system of care. One or more of the above supports may be inadequate or fail.
8. Resolving issues going wrong	Solutions to psychological problems Solutions to support problems	Reduce weight. Profound breathing, gardening, going for a stroll, doing yoga, doing a leisure activity, or tuning in to preferred music. Participating in diabetes guidance programs, interacting with care groups. Involve close relatives or friends for help. They should be completely aware of what is going on with every factor.
9. Advanced methods of intervention	Self-management systems	Self-management kits with instructions on what medications to take and when, self-evaluation of glucose and urine ketone levels, how to change medication estimations, when to call the doctor, etc. Opportunity for regular interactions with other patients and support groups for knowledge updates. Support groups are available round the clock for guidance and emergency calls.
10. New methods of intervention	E-health and m-health	Use of the internet, communication technologies and portable smart devices (smartphones) for: Accessing care resources and facilities in evidence-based practices. Accessing support resources and facilities. Information and knowledge-sharing with

Themes	Subthemes	Variables for modelling requirements
		other patients and support groups. Help with affordability issues.
	E-health effects and impacts	Tele-health opportunities. Remote care. Reduction in the number of hospital visits leading to relief from heavy workload for doctors. Web applications to design intervention programmes for individual patients, especially with complications and comorbidities.
	E-health facilitations	Different types of smartphones with differing enabling environments and limitations. Other mobile devices like personal data assistants (PDAs), tablets, iPhones, notebook personal computers (PCs), wearable medical devices.
	E-health facilitation Upgraded standards	E-health instruments are becoming locally important for helping patients to self-regulate under wearisome conditions. E-health devices can encourage patients to expect greater activity in shared elements with self-organisation and obstruction of adverse conditions in their care, the use of e-health gadgets gives a level of settlement for patients and providers. These instruments exist on the web in different sources and facilitate correspondence, and messages for gaining knowledge. Patients and providers can ask and answer requests at whatever point making the planning perfect and reducing the load on the specialist. Modern devices generally invite patients to upgrade to standard treatment and energise support from social protection providers or companions. Strategies that are beneficial for therapeutic services providers in self-care.

Themes	Subthemes	Variables for modelling requirements
11. Using e-health for in-home self-management	Using smartphones and other gadgets to aid e-health	Self-checking facilitated by smartphones. For advice on medication from doctors. Psychological wellbeing through social interactions and internet-based hobbies. Help patients and relatives/friends with self-checking methods. Improvement of openness to knowledge and information. Help patients in social engagements for viable management of the disease, in their in-home contexts.
	Customised e-health	E-health-related customised medication and other services for each patient according to the needs of the time. Relatives and companions can act as key facilitators of adherence to advice and guidance by helping ill-equipped individuals. Individualised social interaction and support opportunities. For T2D patients, also control of HbA1c.
	Reduction of hospital visits	Mobile telephone (applications). Self-administration of medications. Versatile wellbeing (mHealth) applications of ability and procedure Wellbeing, and other auxiliary results.
	Wellbeing, not just self-care	Versatile wellbeing applications for self-administration and improved and sensible ease with versatile applications. Control of wellness and wellbeing in a holistic manner.
	Smart gadgets as e-health tools	Different diabetes gadgets, insulin siphons, glucose meters and varying capacities in versatile applications. Smartphones with a blend of essential capacities required for self-management in

Themes	Subthemes	Variables for modelling requirements
		one device including data management of blood glucose logging, insulin dose, starch estimation, exercise, designs, seeking hospital visits and for direct contact with services suppliers.
	M-health application facilities	Several openly accessible portable applications for diabetes and diabetes self-administration are growing exponentially. M-health includes the utilisation and exploitation of a smartphone's voice, chatting and messaging applications. The utilisation of GPRS, 3G and 4G internet technologies for faster connections.
12. Integration of m-health with e-health for self-management	Variables of m-health implementation for e-health	M-health can be applied to the progression of health conditions, restorative interventions, cost reductions, direct contact with services, assurance of improved settlement of medical bills, progressively conspicuous personalisation, shortening fundamental courses for educating diabetic patients, rapidly growing scale, speed, and volume of data, transformational influence on patients – all aimed at improving patient satisfaction.
	Variables of some m-health advancements for technological progress	M-health advancements in adjusting clinical fundamentals and improving patient responsibility dynamically underpin the analysts and contract investigating agencies.
	Variables of expectations	M-health helps patient selection and support, productive starting and culmination, giving complete date progressively, infuses calm security and suitability in patients, looking after prosperity needs, increasing convenience and decreasing cost by reducing assessment visits and through online examinations and assessments, helping inpatient preparing and consent necessities and energise support and responsibility through refreshes and online surveys, patients can assist each other with social and emergency assistance.

Themes	Subthemes	Variables for modelling requirements
	Negative variables affecting the positive impact	Economic prosperity driving negative lifestyles, high cost of current diabetic care spending, accessibility, and affordability. Risky nature of certain actions.
13. Identifying variables of a comprehensive e-health self-care system	Personal factors	The extent of commitment, progressively beneficial, having one's data and expectations thwart the headway of a steady affliction, own sentiment of hazard. An individual could improve before a potential ailment strike helped by e-health.
	Care perspectives	Own sentiment of hazard, commitment, careful current partner, identifying elective frameworks, offering scope for control through various medicines or preventive strategies including diet and physical exercise.
	Customised e-healthcare system	Supply people with customised data for better assessment of their wellbeing by including a sentiment of commitment, useful social changes, being dynamic legends of their life, and not as uninvolved recipients of others' decisions.
	Intervention developments	Clinical care qualities related to customised medicine, patients' understanding and responsibility concerning the need, and the subsequent use.
	Application offers	M-health devices contain some common applications and one or two differentiated applications to differentiate them from other devices. When the device is upgraded or a new more advanced model is introduced, these m-health applications are also upgraded and improved. Patients and specialists need to evaluate the applications available for each device and select what is suitable for them with the possibility of upgrades as and when required. Many of the current devices are moderate to satisfactory concerning their multifunctional applications and convenience

Themes	Subthemes	Variables for modelling requirements
		but many of them have insufficient accessibility features. Internet-based guidance for diabetes self-management is logically fruitful in improving glycaemic control and diabetes data when it is customised for individual patients and included the facility to access from anywhere at any time at reduced cost and all of these increase patient responsibility.
	Support groups	Technology-enhanced interventions have generally produced positive outcomes in terms of maintaining healthy glucose and haemoglobin A1c levels in many patients. Diabetes self-organisation practices, self-sufficiency, monetarily efficient and continuous lifetime holistic treatment and prosperity are some other effects. There is also scope for reducing the frequency of things going wrong and increasing the availability of support for solving problems instantly.
	Technological facilitation of positive outcomes	Information highways operate at levels of expectations and actuals leading to good outcomes in terms of weight control and prevention of secondary disease problems.
14. Likely future developments		Wearable devices are already in use and are possible shortly to be involved in e-health. Long-acting insulins. Drugs to prevent the destruction of beta cells. Use of genomic markers for customised drugs. Improved m-health devices for faster access to required information.

The sequence of topics in the thematic analysis is as follows.

1. Predisposing factors of diabetes.
2. The need for diabetes management.

3. Aim of diabetes control.
4. Primary interventions.
5. Achievement of control.
6. Supports.
7. When something goes wrong.
8. Resolving issues going wrong.
9. Advanced methods of intervention.
10. New methods of intervention.
11. Using e-health for in-home self-management.
12. Integration of m-health with e-health for self-management.
13. Identifying variables of a comprehensive e-health self-care system.
14. Likely future developments.

These are depicted in Figure 5.1.

Figure 5.1: Themes identified through the thematic analysis.

The above order of topics was determined to logically lead to the research question to be answered using the focus group responses. The items in the above table have been arranged in the order of the themes in the above table in a clockwise manner. Priorities are for the current situation from pre-disposing factors to using e-health for self-management. M-health to the likely future developments are matters to be considered when they become practical applications.

The discussion participants provided an almost exhaustive list of required variables for modelling e-health for the self-management of diabetes by Saudi patients. Topic 13 lists the requirements of modelling based on themes/topics 1 to 11. Topic 13 was added to identify the scope of future research, which will be one of the outcomes of this research. The respective themes are listed below.

Theme 1: Predisposing Factors of Diabetes

Theme	Subthemes	Variables for modelling requirements
Predisposing factors of diabetes	Hereditary	Some members have diabetes in each generation.
		Structural and functional aspects of genes
	Genomic factors	leading to a lack of blood sugar control.
		Secondary causes.
	Other diseases	Pressure-related hormones can raise glucose levels.
		Obesity.
	Hormonal imbalances	
	Uncontrolled eating quantity	
	Eating junk food containing fats	
	Sedentary work	
	Lack of physical activities	Blood glucose increases.
	Eating a lot of sweet dishes	

These subthemes may be found depicted below in Figure 5.2.

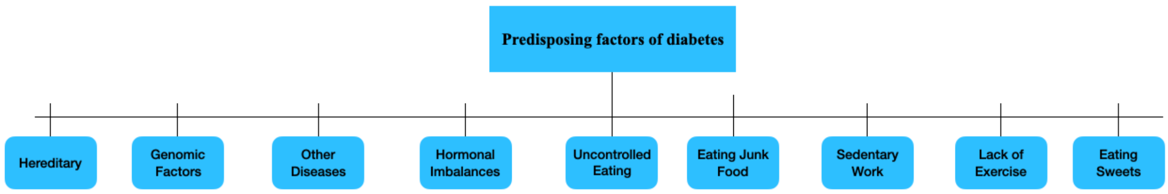

Figure 5.2: Sub-themes identified under Theme 1

Here, pre-disposing factors are considered under the subthemes of hereditary, genomic, other diseases, hormonal imbalance, eating quantity and components, and lack of physical activity. Eating a lot of sweets can be the direct cause of an immediate increase in glucose levels. These predisposing factors determine the likelihood of a person getting diabetes. These factors therefore become modelling variables.

Theme 2: The Need for Diabetes Management

Theme	Subthemes	Variables for modelling requirements
The need for diabetes management	Physiological factors leading to patients requiring abilities for self-management of blood glucose	Glucose in the blood raised beyond the acceptable standards. Not enough insulin production or delivery to the blood. Cells do not react appropriately to the insulin the pancreas produces. High glucose and ketone levels in urine. Lower glucose supply to cells for their development . Patients require instruction and abilities to perform diabetes control self-administration.

There was only one subtheme for Theme 2, as depicted in Figure 5.3.

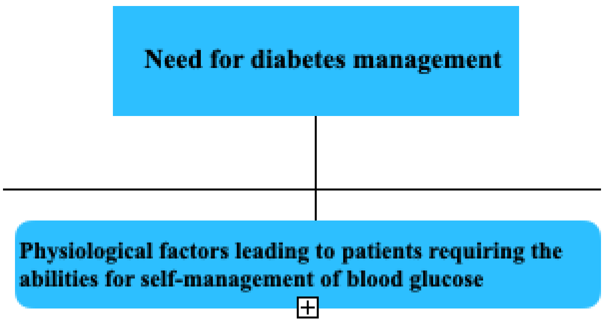

Figure 5.3: Sub-theme identified under Theme 2.

One of the keys aims of this research is to create a model for efficient diabetes management. As there is not currently a cure for diabetes, the disease can only be managed to contain it and prevent adverse outcomes for the patient. Therefore, this theme provides one justification for modelling, but without considering e-health. The need for self-management arises due to any one or more of the physiological factors related to the disease becoming out of control. The most important factors are listed as variables. The last factor, patients requiring instructions and the ability to self-administer diabetes control actions, is the direct reason for the need.

Theme 3: Aim of Diabetes Control

Theme	**Subthemes**	**Variables for modelling requirements**
Aim of diabetes control	Control of direct causes	Reduce blood sugar. Diet control. Physical activities.

There was only one subtheme as given below in Figure 5.4.

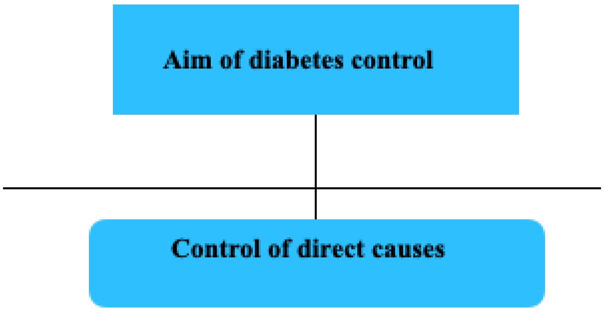

Figure 5.4: Sub-theme identified under Theme 3.

Having realised the need for diabetes management, the main aims are defined here. Management consists of reducing blood sugar, diet control and exercise to maintain this control. This aim is one-half of the modelling aim. The other half will be e-health, which is considered later.

Theme 4: Primary Interventions

Theme	**Subthemes**	**Variables for modelling requirements**
Primary interventions	Therapies Additional interventions	Insulin administration and other medications. Planned diet and exercises or other means of active life.

There were two subthemes, and these are given below in Figure 5.5.

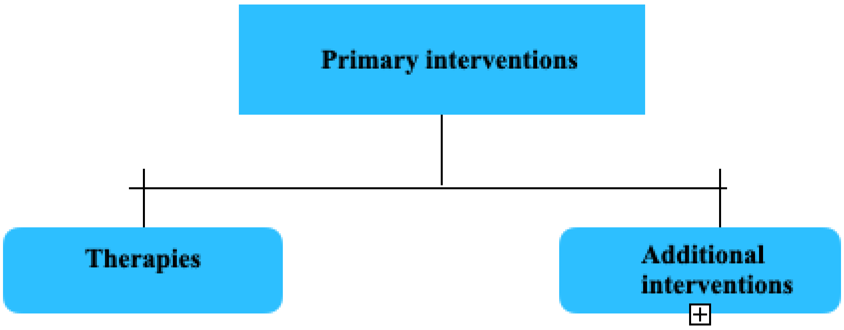

Figure 5.5: Sub-themes identified under Theme 4.

For any diabetes management, the primary interventions consist of the administration of insulin and other medications, especially if there are comorbidities, prescribing a planned diet to avoid foods contributing to an increase in glucose levels, and engaging in physical activities for an active lifestyle, depending on the patient's characteristics like age and occupation. Without these supports, the administration of insulin will be ineffective. Initially, these interventions are implemented under clinical guidance. When the patient becomes sufficiently capable, these steps are practised at home as a part of self-management. These interventions are the basic minimum and thus become essential aspects of modelling for self-management. The core of modelling is how e-health helps in implementing these practices.

Theme 5: Achievement of Control

Theme	Subthemes	Variables for modelling requirements
Achievement of control	Variables of a good control system	Close monitoring of blood glucose and haemoglobin. Other analyses as advised. No psychological problems. Watch menstrual cycle and pregnancy for women.

There was only one subtheme, as depicted below in Figure 5.6.

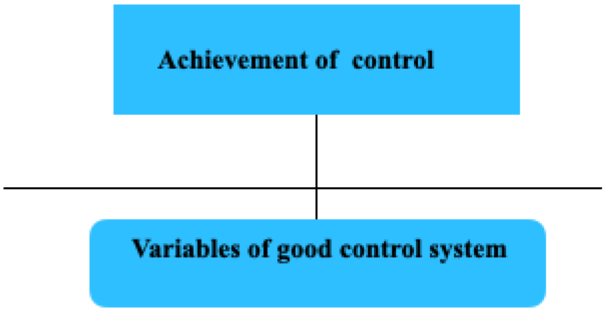

Figure 5.6: Sub-theme identified under Theme 5.

The variables of a good control system can be viewed as a guideline for modelling. Here, to achieve control of blood glucose levels the close monitoring of glucose and haemoglobin (HbA1c) is essential. Other analyses like measuring body weight and selected enzyme activities may be advised depending on requirements. Psychological problems like stress and anxiety can increase blood glucose levels even if insulin is not required and hence need to be addressed through awareness and counselling. For women, controlling diabetes during menstrual cycles and pregnancy is critically important.

Theme 6: Supports

Theme	**Subthemes**	**Variables for modelling requirements**
Supports	Clinical support	The doctor advises on the medical interventions.
	Community support	Social support groups for diabetes patients conduct awareness camps and training classes and provide information and advice, help in crises.
	Administration support	Ensure adequate availability of resources to the patients with easy access and affordability.
	Insurance support	Help patients in bearing the high costs of treatment.

There were four subthemes, which are depicted below in Figure 5.7.

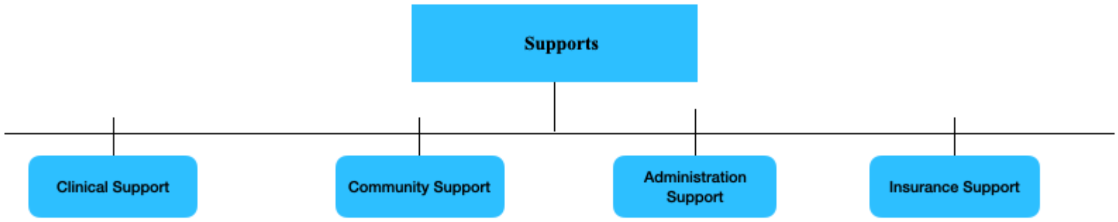

Figure 5.7: Sub-themes identified under Theme 6.

Self-management may require support from many sources since the facilities of a hospital are not available at home or often even in the close vicinity of the home. The patient may be unsure of what steps to take when problems arise, as was exemplified by an episode discussed in the focus group (i.e., when there were three high sugar readings). Clinical support from the patient's hospital may be available on call. The community in which the patient lives may include patients already experienced in self-management. Many organisations provide free classes, advice and guidance and may even extend physical help when required. Administrative support from the government is necessary to ensure an adequate supply of resources that can be easily accessed and affordable. Insurance firms need to take a compassionate view in helping patients who are poor and cannot afford long-term self-management costs. All these supports are built into the population diabetes control in most countries. These supports are particularly relevant in e-health also. This aspect is, therefore, important in modelling.

Theme 7: When Something Goes Wrong

Themes	**Subthemes**	**Variables for modelling requirements**
When something goes wrong	Specific intervention failures	Irregular blood glucose levels requiring closely monitored insulin administration. Non-availability of insulin and other drugs at critical times. Failure in addressing other complexities or comorbidities like cardiac or renal problems as indicated by higher levels of albumin or proteins in urine. Side effects of drugs.

	Psychological problems	Diabetic neuropathy harms the nerves, influences warmth, cold and agony, increasingly vulnerable to injury, not noticeable and these wounds develop into genuine complications. Feeling pushed, desolate or incensed. Pondering and worries due to mental strain. Stress can raise blood glucose levels. Other complications like cerebral problems and stroke.
	System failures	Sudden catastrophic developments can jeopardise the entire system of care.
	Failure of any one or more supports	One or more of the above supports may be inadequate or fail.

There were four subthemes, as shown in Figure 5.8.

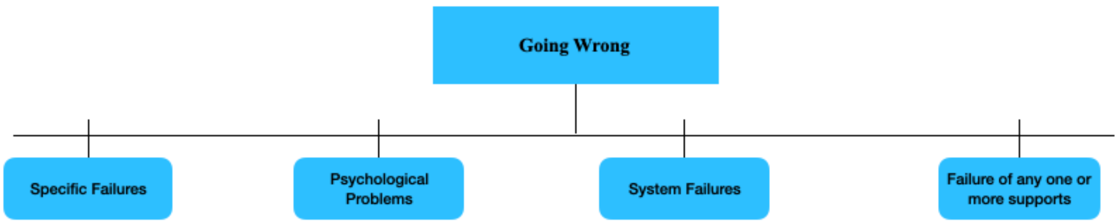

Figure 5.8: Sub-themes identified under Theme 7.

Even in the most perfect system, something can always go wrong. The diabetes self-management system is no exception. An imperfect list of things that can go wrong provides the modelling with variables to ensure the minimum disturbance to the self-management system. Problems that can happen include failures of interventions, development of psychological problems, support failures and whole system failures due to catastrophic reasons. These failures need to be factored into the model to save the system from crashing.

Theme 8: Resolving Issues Going Wrong

Instead of trying to prevent failures, it is more prudent to implement steps to resolve them in advance. This should be how the model behaves. Solutions to intervention problems need direct actions when they occur. We cannot predict catastrophic risks in advance. Thus, only psychological and support problems can be foreseen and controlled before they fail. These are listed under the eighth theme.

Theme	**Subthemes**	**Variables for modelling requirements**
Resolving issues going wrong	Solutions to psychological problems	Reduce weight. Profound breathing, gardening, going for a stroll, doing yoga, doing a leisure activity, or tuning in to preferred music. Participating in diabetes guidance programs, interacting with care groups.
	Solutions to support problems	Involve close relatives or friends for help. They should be completely aware of what is going on with every factor.

There were two subthemes, as depicted in Figure 5.9.

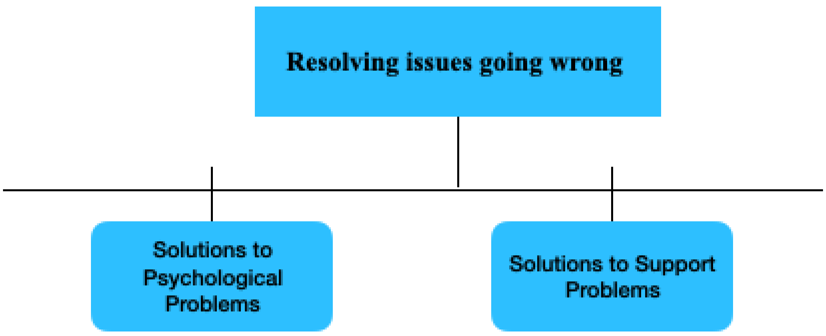

Figure 5.9: Sub-themes identified under Theme 8.

Theme 9: Advanced Methods of Intervention

Theme	**Subthemes**	**Variables for modelling requirements**
Advanced methods of intervention	Self-management systems	Self-management kits with instructions on what medications to take and when, self-evaluation of glucose and urine ketone levels, how to change medication estimations, when to call the doctor, etc. Opportunity for regular interactions with other patients and support groups for knowledge updates. Support groups are available round the clock for guidance and emergency calls.

There was only one subtheme, as shown in Figure 5.10.

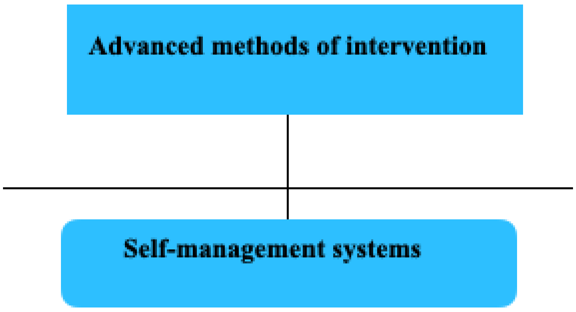

Figure 5.10: Sub-themes identified under Theme 9.

Some advanced methods of intervention may be failure-proof to a great extent and therefore important in modelling. Self-management kits with instructions and interaction opportunities with round-the-clock support perform like e-health systems.

Theme 10: New Methods of Intervention

Theme	**Subthemes**	**Variables for modelling requirements**
New methods of intervention	E-health and m-health	Use of the internet, communication technologies and portable smart devices (smartphones) for: Accessing care resources and facilities in

		evidence-based practices. Accessing support resources and facilities Information and knowledge sharing with other patients and support groups. Help with affordability issues
	E-health effects and impacts	Tele-health opportunities Remote care Reduction in the number of hospital visits leading to the relief from heavy workload for doctors. Web applications to design intervention programmes for individual patients, especially with complications and comorbidities.
	E-health facilitations	Different types of smartphones with differing enabling environments and limitations. Other mobile devices like personal data assistants (PDA), tablets, iPhones, notebook personal computers, wearable medical devices.
	E-health facilitation	E-health instruments are becoming locally important for helping patients to self-regulate under wearisome conditions. E-health devices can encourage patients to expect greater activity in shared elements with self-organisation and obstruction of adverse conditions in the care, the use of e-health gadgets gives a level of settlement for patients and providers. These instruments exist on the web in different sources and facilitate correspondence and messages for gaining knowledge. Patients and providers can ask and answer requests at whatever point making the planning perfect and reducing the load on the specialist. Modern devices like wearable devices

	Upgraded standards	connected to e-health and cloud storage of data and other information for evidence-based interventions by and large invite patients an upgrade to standard treatment, and energise support from social protection providers or companions, strategies that restorative administrations providers, in self-care.

There were four subthemes, as depicted in Figure 5.11.

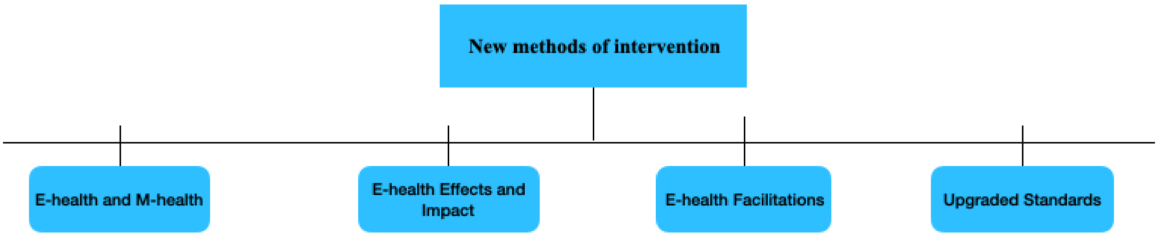

Figure 5.11: Sub-themes identified under theme 10.

We now consider e-health to ensure that the diabetes self-management system works as well as possible. M-health is the application of e-health using mobile (smart) phones and other devices. How mobile phones function is facilitated for this and makes possible elevated standards of care, as described in the theme, are important in modelling.

Theme 11: Using E-health for In-home Self-management.

Theme	**Subthemes**	**Variables for modelling requirements**
Using e-health for in-home self-management	Using smartphones and other gadgets to aid e-health.	Self-checking facilitated by smartphones. For advice on medication from doctors. Psychological wellbeing through social interactions and internet-based hobbies. Help patients and relatives/friends with self-checking methods. Improvement of openness to knowledge and information. Help patients in social engagements for viable management of the disease, in their in-

		home contexts.
	Customised e-health	E-health-related customised medication and other services for each patient according to the needs of the time. Relatives and companions can act as key facilitators of adherence to advice and guidance by helping ill-equipped individuals. Individualised social interaction and support opportunities. For T2D patients, also control of HbA1c.
	Reduction of hospital visits	Mobile telephone (applications), self-administration of medications, versatile wellbeing (m-health) applications of ability and procedure, wellbeing, and other auxiliary results
	Wellbeing, not just self-care	Versatile wellbeing applications for self-administration and improved and sensible ease with versatile applications, control of wellness and wellbeing in a holistic manner.
	Smart gadgets as e-health tools	Different diabetes gadgets, insulin siphons, glucose meters and varying capacities in versatile applications. Smartphones with a blend of essential capacities required for self-management in one device including data management of blood glucose logging, insulin dose, starch estimation, exercise, designs, seeking hospital visits and for direct contact with services suppliers.
	M-health application facilities	The number of openly accessible portable applications for diabetes and diabetes self-administration is growing exponentially. M-health includes the utilisation and exploitation of a cell phone's voice, chatting and messaging applications. The utilisation of GPRS, 4G and 5G internet technologies for faster connections.

There were six subthemes under Theme 11, which are depicted in Figure 5.12.

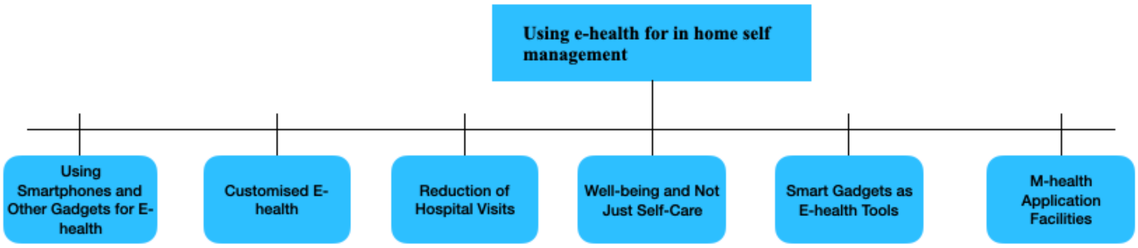

Figure 5.12: Sub-themes identified under Theme 11.

Earlier, we considered the requirements of self-management. Now we examine how e-health facilitates self-management, making it an e-health enabled system. The concept of e-health is developed around the holistic health of the individual. Three important components of e-health are physical health, mental health, and wellbeing (not just limited to self-care). Using smartphones and other smart gadgets makes it m-health. M-health customises e-health for individual needs, especially as the focus of this model is the self-management of diabetes. A reduction of hospital visits reduces the workload of physicians, as the entire range of interventions can be practised using mobile devices. Some specific m-health applications are also considered here.

Theme 12: Integration of M-health with E-health for Self-management

Theme	Subthemes	Variables for modelling requirements
Integration of m-health with e-health for self-management	Variables of m-health implementation for e-health	M-health can be applied to the progression of health conditions, restorative interventions, cost reductions, direct contact with services, assurance of improved settlement of medical bills, progressively conspicuous personalisation, shortening fundamental courses for educating diabetic patients, rapidly growing scale, speed, and volume of data, transformational influence on patients – all aimed at improving patient satisfaction.
	Variables of some m-health advancements for technological progress	M-health advancements in adjusting clinical fundamentals and improving patient responsibility dynamically underpin the analysts and contract investigating agencies.
	Variables of expectations	M-health helps patient selection and support, productive starting and culmination, giving complete dates progressively, infuses calm

		security and suitability in patients, looking after prosperity needs, increasing convenience and decreasing cost by reducing assessment visits and through online examinations and assessments, helping inpatient preparing and consent necessities and energise support and responsibility through refreshes, and online surveys, patients can assist each other to give them social assistance.
	Negative variables affecting the positive impact	Economic prosperity driving negative lifestyles, high cost of current diabetic care spending, accessibility and affordability, risky nature of certain actions.

There were four subthemes for Theme 12, as shown in Figure 5.13.

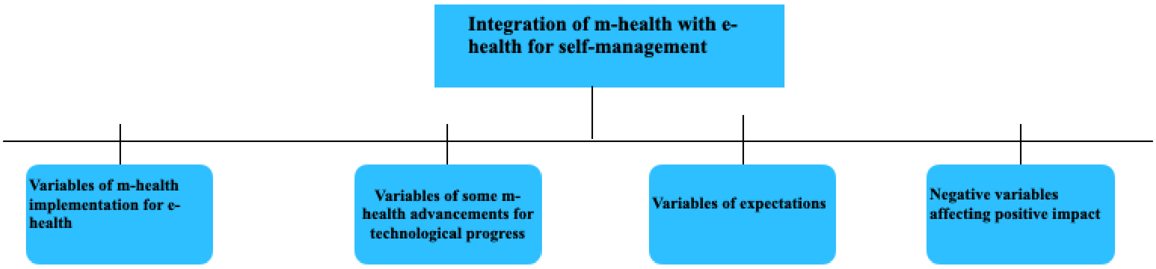

Figure 5.13: Sub-themes identified under Theme 12.

Given that m-health is only the facilitation of e-health-based self-management of diabetes using mobile devices, how exactly m-health is integrated with e-health becomes important in modelling for e-health in which m-health is the tool. The current capabilities of m-health that are compatible with e-health, the possibilities of further technological advancements in mobile devices, and what to expect when incorporating m-health with e-health in this model determine how far the integration of m-health with e-health can go. Some possible negative variables also exist. For example, one negative factor is if the patient engages in a lifestyle not conducive to diabetes self-management. Another matter of serious concern is affordability and accessibility for rural and remote locations. Internet connectivity, rural income limitations and distant care facilities are the problems in this respect.

Theme 13: Identifying Variables of a Comprehensive e-Health Self-care System.

Theme	Subthemes	Variables for modelling requirements
Identifying variables of a comprehensive e-health self-care system	Personal factors	The extent of commitment, progressively beneficial, having one's data, and expectations, thwart the headway of a steady affliction, own sentiment of hazard.
	Care perspectives	An individual could improve before a potential ailment strike helped by e-health,
		Own sentiment of hazard, commitment, careful current partner, identifying elective frameworks, offering scope for control through various medicines or preventive strategies including diet and physical exercise.
	Customised e-healthcare system	Supply people with customised data for better assessment of their wellbeing by including a sentiment of commitment, useful social changes, being the dynamic legends of their life and not uninvolved recipients of others' decisions.
	Intervention developments	Clinical care qualities related to customised medicine, patients' understanding and responsibility concerning the need and the subsequent use.
	Application offers.	M-health devices contain some common applications and one or two differentiated applications to differentiate them from other devices. When the device is upgraded or a new more advanced model is introduced, these m-health applications are also upgraded and improved. Patients and specialists need to evaluate applications available in each device and select what is suitable for them with the possibility of upgrades as and when required. Many the current devices are moderate to satisfactory concerning their multifunctional applications, and convenience and many of them have insufficient accessibility features.
		Internet-based guidance for diabetes self-

		management is logically fruitful in improving glycaemic control and diabetes data when it was customised for individual patients and facility to access from anywhere at any time at reduced cost and all this increase patient responsibility.
	Support groups	Technology-enhanced interventions have generally produced positive outcomes in terms of maintaining healthy glucose and haemoglobin A1c levels in many patients. Diabetes self-organisation practices, self-sufficiency, monetarily smart and continuous lifetime holistic treatment, prosperity and are some other effects. There is also scope for reducing the frequency of going wrong and increasing the availability of support for solving problems instantly.
	Technological facilitation of positive outcomes	Information highways operate at levels of expectations and actuals leading to good outcomes in terms of weight control and prevention of secondary disease problems.

There were seven subthemes under Theme 12, which are shown in Figure 5.14.

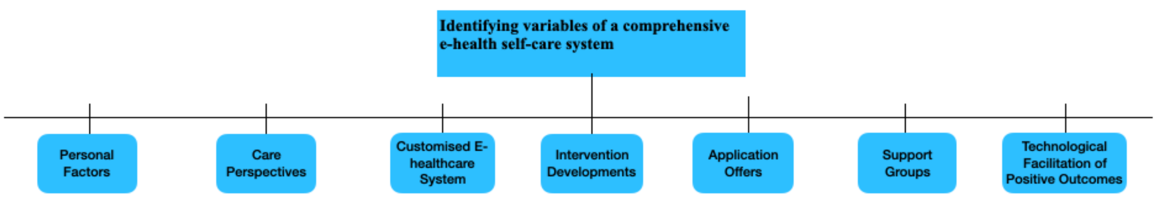

Figure 5.14: Sub-themes identified under Theme 13

Theme 13 is directly related to the aim of developing a model in this research, as was highlighted in the introduction to this chapter. The variables related to the question of what the design requirements are for modelling an m-health facilitated e-health system for diabetes self-management are described here. It is almost a summary of the variables considered above in terms of personal factors, care factors, customisation, and developments in interventions, mobile applications, support groups and technological facilitations. One considerable drawback with these requirements is that there is nothing specific about the

Saudi Arabian context. The focus group questions did not specifically ask about the Saudi context. However, in applying m-health integrated e-health systems for diabetes self-management by Saudi patients, the status of all these variables in Saudi Arabia will be considered. For example, data on the average profile of a Saudi diabetes patient, gender separation problems in the diabetes care of women, the social and cultural environment determining community support, the compatibility of the current e-health system with diabetes self-management, the availability of mobile devices and apps related to diabetes self-management, internet penetration and access, the costs of diabetes management in urban, rural and remote areas, the average family income, and the percentage of healthcare expenditure are relevant and considered here.

Theme 14: Likely Future Developments

Theme	**Subtheme**	**Variables for modelling requirements**
Likely future developments		Wearable devices are already in use, and more are possible soon. Long-acting insulins. Drugs to prevent the destruction of beta cells. Use of genomic markers for customised drugs. Improved m-health devices for faster access to required information.

Theme 14 is an attempt at fortune-telling to a limited degree to foresee future research opportunities to end this thematic analysis. The list includes some possible avenues of future developments where some progress has already been made and research is being done. For example, some wearable devices and long-acting insulins are already commercially available and improved versions are under development. The destruction of pancreatic beta cells has been traced as the origin of diabetes development. A lot of research into this and the genomic and biochemical aspects of diabetes has already been done and the search for genomic markers continues, with promising results reported. As the understanding of the genetics of diabetes grows, some of this research may pave the way to prevent diabetes altogether and thus contribute to healthy and more active national populations.

5.3 Conclusion

A focus group was conducted with the aim answering the question “What is the current situation of e-health in Saudi Arabia?” A focus group was conducted with four each of diabetes patients, doctors and nurses, IT specialists and close relatives and friends of diabetics. A total of 14 themes were identified using a thematic analysis.

Chapter 6 – Discussion

6.1 Introduction

This research brings together all the work done in the previous chapters and aims to identify the design and process engineering requirements so that an efficient and effective e-health-based personalised diabetes management model can be created and implemented. To do this, the modelling requirements need to be identified.

Eysenbach (2001) lists three requirements of e-health modelling. The first of these is business to consumer (B2C), which is the capability of patients for online interaction with their healthcare systems. In this research, the capability of patients indicates their awareness and education about diabetes, its symptoms, and the intervention methods to manage the disease. On the side of healthcare systems, the capability is related to the availability of electronic patient records for instant reference, evidence-based interventions, the availability of diabetes specialists, and communication facilities with the patients. The second requirement is business to business (B2B), which is the improved possibilities for institution-to-institution transmissions of healthcare data for common benefit as evidence-based medicine. This involves the communication of healthcare data and intervention recommendations with local healthcare systems, community health workers and new patients through diabetes communities' networks. The third requirement is consumer to consumer (C2C), which is new possibilities for communication and cooperation among similarly placed patients, especially concerning the self-management of chronic diseases. This includes communications among diabetes patients within networks of diabetes communities and with new patients enrolled in these networks.

6.1.1 Requirements for e-health modelling

As mentioned above, the three requirements of e-health modelling are B2C, B2B and C2C. Amplifying this list of requirements for e-health modelling further, the following list identifies the different levels of the healthcare system and the information and activities at each level:

1. Patient: Results of self-monitored blood glucose levels, foods eaten, physical activity details, any other acute and chronic healthcare problems as and when they occur, and

interventions done as per local healthcare recommendations and job details. Also, family details including their health problems with interventions done.

2. Local healthcare systems: Patient healthcare records containing details of visits, tests, diagnoses, and recommended interventions.
3. Local community health workers: Ensure that the patient-level data listed in the previous item are available at the appropriate levels by monitoring, correcting, and advising the patients. Educating patients.
4. Centralised healthcare systems covering a large area: Interaction and communication with local healthcare systems, community health workers and community networks, instantly attending to alerts from local systems about any patient, and the maintenance of a centralised healthcare data of all patients around its jurisdiction. Communication of new evidence-based interventions and revised guidelines to all concerned as and when revisions are done.
5. Community networks of diabetes patients: Interactions with healthcare systems and professionals for expert inputs, interactions with community health workers for local-level actions, and interactions among members sharing experiences useful for others.

Theme 13 of the focus group results was "Identifying variables of a comprehensive e-health self-care system." The variables can be related to items in the list to establish a relationship, as shown in Table 6.1.

Table 6.1: Relationship of required activities and Theme 13 items of the focus group

Level	Required activities	Variables from Theme 13 from the focus group analysis
Patient	Results of self-monitored blood glucose levels, foods eaten, physical activity details, any other acute and chronic healthcare problems as and when they occur, interventions done as per local healthcare recommendations, and job details. Also, family details including their health problems with interventions done. Enter this information in an electronic data system for use in customised e-health self-management systems.	The extent of commitment, progressively beneficial, of having one's data and expectations thwart the headway of a steady affliction, own sentiment of hazard. An individual could improve before a potential ailment strikes, helped by e-health. Own sentiment of hazard, commitment, careful current partner, identifying elective frameworks, offering scope for control through various medicines or preventive strategies including diet and physical exercise.
Local	Store electronic patient data and	Receive from a centralised facility customised

Level	Required activities	Variables from Theme 13 from the focus group analysis
healthcare systems	transmit it to the central system also. Advise interventions to the patients on visits. Visit patients at home frequently to ensure compliance with intervention advice. Advice to patients on customised m-health applications.	data for patients in the locality, better assessment of their wellbeing by including a sentiment of commitment, useful social changes, being dynamic legends of their life, not as uninvolved recipients of others' decisions. Include them in the intervention advice to the patient concerned.
Centralised healthcare systems	Interaction and communication with local healthcare systems, community health workers and community networks, instantly attending to alerts from local systems about any patient, maintenance of centralised healthcare data of all patients in the area of its jurisdiction. Communication of new evidence-based interventions and revised guidelines to all concerned as and when revisions are done and customised m-health applications.	Store electronic health data of all patients in its jurisdiction. Combine them with evidence-based interventions for customised advice and transmit them to local healthcare systems for their advice to the concerned patient. Work with local systems and community networks to ensure clinical care qualities related to customised medicine, patients' understanding and responsibility concerning the need and continued use. Test, and evaluate mobile applications of customised self-care of patients and recommend them to local systems and community networks for use.
Community networks of diabetes patients	Interactions with healthcare systems and professionals for expert inputs, interactions with community health workers for local level actions, and interactions among members sharing experiences useful for others.	Collect all useful information from centralised and local healthcare systems and other sources and relate them to actual patient experiences to derive useful advice for the network members. Use internet-based interactions with patients to exchange useful methods of customised management and mobile applications.

Based on the above table and the results of the surveys, the design requirements for modelling an e-health system for the self-management of diabetes in Saudi Arabia are defined below.

1. Patients: Targeted customised intervention. The variables to consider in modelling are demographic profile, diabetes profile and interventions. These are explained in detail as follows:

a) Demographic profile: Diabetes is more common among women of all ages, especially 25 to 50 years of age, with a secondary school education or a degree, unemployed or a government employee and with monthly income lower than 15,000 SAR. The target group for customisation needs to be done on this basis. Also targeted should be people older than 50 years and women during their menstrual cycles and pregnancy.
b) Diabetes profile: Requiring special attention in customisation and m-health – T1D for over five years. Higher stress is to be placed on strictly following diet and physical activity recommendations.
c) Interventions: Medications, diet, and exercise. In the survey results, a reduction in blood sugar levels was noted in this order of interventions; however, the regression equation was possible based on exercise only. To avoid the risks of focusing only on one intervention, all three interventions will be included in the e-health model.

2. Patients' homes facilitating the self-management of diabetes.

3. Hospitals: Self-care management systems attached to the nearest diabetes care speciality hospital and ultimately to the Ministry of Health database. Patient–doctor communication is to be facilitated using smartphone applications like WhatsApp and short message services (SMS).

4. Healthcare systems: The requirements for healthcare systems are:

a) Increase registration of patients for hospital-based e-health self-care management programme.
b) Mobile facilitated e-health (m-health) with cloud storage of data with adequate security steps may be ideal. The electronic health records of patients with visibility for both the concerned patient and the doctor and a knowledge base for evaluating the latest evidence on diabetes management can be linked to this communication system so that the doctor can advise based on this information.
c) Variables of customised e-health self-care programme: Regular blood glucose monitoring, insulin injections, daily food intake and physical activity program as per physician's advice and which is entered into the e-health system by the patient/healthcare professional on the day of any appointments. Enter any other

chronic health problems in the system. Contact local healthcare systems for acute conditions and get treated. Alert the healthcare systems on any serious problems for urgent attention.

d) Desirable: Use local healthcare centres and community health workers for maximum benefit. Patients are motivated to become members of diabetes community groups in the area and to participate in discussions and interactions, sharing their experiences and learning from others. Social group workers need to be trained appropriately for handling varying and critical situations in their areas.

e) Scope for introducing wearable devices to be examined and introduced when required and connected to the m-health system.

f) Improvements in the above design are based on monitoring outcomes in terms of the design variables and periodical reviews.

6.2 How the identification of e-health design requirements helps to design and implement efficient and effective e-health-based personalised diabetes management.

The components of the care coordination homecare telehealth (CCHT) model for chronic care program introduced by the Veteran Health Association (VHA) in the United States of America (USA) in 2003 for veterans with chronic illnesses were discussed by Darkins et al. (2008). These components targeted more vulnerable older males, trained care staff and cost reduction and used standardised clinical, technological, and managerial methods. Five years of implementation of the CCHT model showed a substantial reduction in the number of care bed days, a reduction in the number of hospital admissions and an increase in patient satisfaction, all leading to an increasing number of registrations during the five years. An extra point applicable from this paper to this research is the element of training. Community health workers can be adequately trained in e-health management aspects so that they can guide patients effectively in the self-management of diabetes. Targeted attention to older patients is also a factor to consider. All these points have been incorporated into the design of the current e-heath model.

In an e-health system, effective patient–physician communication is the most important aspect. In this research, the communication between the patient and the doctor was facilitated in both local healthcare centres and centralised hospitals. Additional facilitation of mobile applications like WhatsApp and SMS have been included in the design requirements. This is an essential component of the m-health system proposed here, which was supported by the focus group participants. In the University of Pittsburgh Medical Centre (UPMC) HealthTrak diabetes self-management model, physicians are connected with the patients via electronic medical record (EMR). Mobile applications are a convenient way to access EMRs. The e-health model consisted mainly of secure electronic communication between patients and the physician's office to advise them on preventive healthcare reminders and tools and information related to diabetes. During the initial four years following the model's implementation, neither the number of patient encounters nor the telephone messages changed; however, HealthTrak (the diabetes self-management model) messages increased. Although communication was improved, the patients could not access lab reports and they were not given access to the hospital EHR to evaluate their conditions themselves. Messages from the physicians to the patients were also not answered. The finding of Hess et al. (2007) highlights the importance of two-way responsive interactions for e-health models to be effective. Two-way interactions between the patient and the doctor can be ensured by provisioning for an alert signal when there is no response for a certain duration, which is used in the model is designed in this research.

A systematic review by Blaya et al. (2010) showed promising results for e-health systems in developing countries if they facilitate communication between institutions, order and manage medications, and monitor and detect early those patients who might abandon care. M-health appeared to be effective in increasing access to healthcare. The findings of this research also show the importance of interactive communications between patients and local level hospitals and the central hospital for the area, community health workers and the network of diabetes groups. In related work, Paschou et al. (2013) designed and implemented an e-health mobile application. Unlike the already available applications, their application provided the ability to create their own smartphone applications, which were data-intensive and independent of the desired healthcare domain. The development part was not visible to users, thus enhancing its utility. In this research, the topics of e-health and mobile applications were components of focus group questions 5, 6, 7 and 9. The responses to these questions were thematized and have been included in the design requirements above. This information is used in the model's design.

In a meta-review of e-health research done by Ross et al. (2016), the important implementation components based on the Consolidated Framework for Implementation Research (CFIR) method were individual e-health technology, the outer setting, the inner setting, the individual health professionals, and the implementation process. The original CFIR framework consists of intervention characteristics, inner setting, outer setting, characteristics of individuals related to implementation and the implementation process (Keith et al., 2017). All the CFIR components except for the implementation process are included in the above model design requirements. The inner setting is that of the patient with an immediate outer setting of the health professionals in care hospitals, individual health technology is a patient-based care system based on medications, diet and exercise, and the outer setting is close friends and relatives, the local diabetics' groups, and other community health workers. The implementation process is only relevant after designing a model and its validation.

A literature review and discussion and quantitative analysis of data done by Ekroos and Jalonen (2007) revealed the potential of e-health to provide evidence-based interactive tools for efficient patient empowerment that enhance the self-management of diabetes and improve workflow and patient–provider communication. The aim of this research is also to achieve all potential benefits, of which a reduction in the prevalence of diabetes in Saudi Arabia is the first in importance.

Many developments have taken place in recent years. They include big data analysis, cloud storage and computing, the Internet of Things (IoT), mobile-based applications and improved accessibility. This is evident from the results of a survey of e-health in diabetes self-management by NandhaKumar and Thanamani (2017). They note the benefits of cloud computing for the retrieval of EHRs from different regions, times and working hours. Access to effectively retrieve and share health records, which have the characteristics of big data, has been made easier by data-mining techniques. The components of the e-health model proposed by the authors were building healthcare data-mining services, disease diagnosis, clinical support system architecture, efficient data access control, and self-management applications. Health records are maintained in the hospital with the support of information and technologies for storage, additions, deletions, and retrieval. The model requirements identified above already include cloud storage with sufficient security settings. Big data analytics has scope when sufficient data has accumulated. Cloud-based e-health solutions for patients in remote areas were also suggested by Miah et al. (2017).

In cases when patients are not sufficiently literate or have difficulty in understanding, the e-health system should be a form of coaching. In this respect, the Diabetes Digital Coach was the UK digital platform of the UK's NHS for mobile-used self-management by diabetes patients. IoT test beds were used. The IoT was used mainly for implementing interconnected digital innovations in health and social care. The test bed consisted of tools for patient education, wearable sensors, and supporting applications and services to ensure that Type 1 and Type 2 diabetic patients could do the right thing at the right time in their self-management of health conditions (Winterlich et al., 2016). In a review, Scarpato et al. (2017) note that IoT devices possess the capability of improved access to care, reduction in the cost of healthcare, and increase in the quality of life of patients. The authors reviewed IoT applications, wearable devices, and the security and privacy of IoT. They identified response time and precision as two problems that may need to be addressed in the development of IoT-based e-health applications. The emerging trends in cloud computing and IoT can be part of the e-health designed from this research. There is a likelihood of some significant percentage of low literacy levels among Saudi patients, especially women, as the demographic details of the survey show. In the survey, 57 percent of participants were females and about 34 percent had an education level of high school or less. It is possible that some or many of this 34 percent may be illiterate. The education of diabetic patients can be done by local community health workers and in the Saudi Arabian context, female workers among them can educate female patients. So, a separate coaching system may not be required.

The gold standard of health care is when the patient can talk to a physician directly and get advice. E-health can only imitate face-to-face interactions in the best possible manner. Not all diabetes patients may be interested in e-health for self-management. This was revealed to King et al. (2012) by patients in focus groups and discussions, who stated they preferred face-to-face contact. However, the e-health system is the next best option to face-to-face health care. The only point of interest in e-health for the patients in King et al.'s (2012) study was its self-management inputs. These patients were concerned about the choice of technology, personalised instruction in using the program features, and the facilitation of exchanging information with their healthcare team. Regarding the inclusion of other persons in the virtual social support systems, their opinions were diverse. This was due to privacy concerns.

In an undergraduate thesis, Tan (2014) interviewed nurses specialising in diabetes care to understand their views on e-health and m-health for self-management by patients. Regarding e-health, the study revealed that the definition of e-health depends on the kind of e-health system used; the effects on patients are different for different types of e-health technologies;

the workload of nurses is increased by the practice of e-health; nurses have a negative mediating effect on the interaction between patients and e-health systems; and there is a higher frequency of nurse–patient interactions in e-health. The nurses were not able to define m-health and they had mixed attitudes towards it. Although there were both positive and negative attitudes from nurses, all the nurses described requirements for the expanded use of m-health in future. However, the nurses admitted that patients were more aware than the nurses about m-health. Here, one important point may be that m-health patients are more independent in managing their problems themselves using mobile applications, so they have less need to depend on nurses or physicians for advice. Considering the results of this research in relation to the design of an e-health model for Saudi Arabia, the role of nurses in the system should be clearly defined. The focus group of this research contained a few nurses, but they were not asked questions related to their role. This means including them in an e-health system can only be done only after a study like Tan's (2014) is conducted.

The Office of the National Coordinator for Health Information Technology in the Department of Health and Human Services in the USA leads the strategy in the country to increase electronic access to health information, support the development of tools that enable people to act with that information, and shift attitudes related to the traditional roles of patients and providers. Ricciardi et al. (2013) showed that e-health care is a national priority, and that laws, regulations, policies, institutions, and government strategies determine the effectiveness of any e-health program in any country. Ricciardi et al.'s (2013) research is relevant to this study because in Saudi Arabia's case, it is a national priority arising from the rapid increase in diabetes and its effect on the national economy.

When e-health is implemented with applications for mobile phones, it becomes m-health. Several studies have researched various aspects of m-health in detail. The usefulness of the m-health concept for the self-management of diabetes has been demonstrated by many researchers. In a systematic review, Holtz and Lauckner (2012) observed that the use of mobile phones for diabetes self-management improved self-efficacy, self-management, and the monitoring of haemoglobin by the patients.

The main components for most m-health applications are environments including hospitals, clinics, long-term care facilities, primary care providers and homes to effectively deal with acute, emergency, chronic, primary and outpatient care integrated in an overlapping and interacting manner. The critical variables of e-health implementation success as a business include usability, adoption, interoperability, change management, risk mitigation, security, and privacy, and return on investment (Archer, 2007). There are enough pointers from the data collected in this research that all these components have been included in the design requirements listed above.

A review and evaluation of iOS devices from the Apple App Store by Liu et al. (2011) proved their usefulness, although the researchers found that further improvements were possible. Weekly m-health interventions were useful in improving the self-management of diabetes patients, especially concerning compliance with interventions prescribed, physical function and psychological adjustment. This innovative idea is inexpensive and can lead to many benefits and prevent complications in diabetes (Aikens et al., 2015). The scope of integrating wearable devices with sensors into m-health was discussed by Istepanian et al. (2004). In the design requirements of the Saudi self-management system for diabetic patients, the scope for introducing wearable devices will be examined and introduced when necessary. Administration aspects, patient healthcare insurance and all payments, and medical connectivity were listed as future research topics. Expected challenges were methods of rapid response to critical medical care irrespective of geographical regional barriers, fast and flexible access to experts, increased management and empowerment in rural remote areas, early warnings through intelligent monitoring systems, very fast management of critical patients during natural or manmade disasters, specific focus on topics like healthy lifestyles, and the synergy of patient health information from sensors to provide an understanding of the broader physiological condition of the patient. There are also technical, economic, and social issues. With the high frequency of daily voice and text messages in the m-health application for diabetes self-management, Krishna et al. (2009) observed significant improvements in compliance with medicine taking, asthma symptoms, HbA1C, stress levels, smoking quit rates, and self-efficacy on patient side effects. Process improvements of reduced appointment failures, quicker diagnosis and treatment, and improved teaching and training were also noted.

Fatehi et al. (2017) considered the usefulness of m-health for diabetes care. The parameters of success in m-health and the benefits it can provide for the stakeholders remain unclear. The authors discuss the findings of various studies on using m-health for diabetic control. Compliance with medication and advice and providing feedback to the physician are two factors of first-level importance. When this is assured, other things can be connected to this through the interaction of other variables. A successful example of collaboration between the physician and the patient in a cloud-based m-health self-management system was provided by Hsu et al. (2016). In this case, the insulin injection was initiated and titrated against glycaemic control.

The e-Health Implementation Toolkit (e-HIT) is an example of a tool designed within the NHS UK context to promote the implementation of e-health services. Its utility in international settings was evaluated by MacFarlane et al. (2011) in Scotland, Sweden, Finland, and Norway. The results indicated the utility of e-HIT in the international context of different e-health systems. The practitioners across these four countries expressed a positive attitude towards its usefulness.

The research discussed in this section raises an important consideration for m-health in Saudi Arabia: whether it should be Android or iOS based. The decision on this depends upon whether all the diabetes patients use the same type of mobile phone. However, such a possibility is rare. That means the e-health system should be usable for owners of both Android and iOS operating systems and needs to be designed accordingly.

A good e-health example integrating mobile, cloud and wearable devices was proposed by Kafalı et al. (2013), who developed an application platform named COMMODITY12. It is a personal health system (PHS) that facilitates the provision of continuous and personalised health services to diabetic patients. The patients are thus empowered in adopting a healthy lifestyle, even when they access the PHS from rural and remote locations. The system components are ambient, wearable, and portable devices to acquire, monitor, and communicate physiological parameters and other health-related aspects of the patient like physical activity and vital body signals. Intelligent agents use expert biomedical knowledge to derive important insights about the individual’s health status from these data. The findings of the intelligent agents are provided as feedback from the device to the patient directly or through health professionals. Healthcare professionals use the data for diagnosis, treatment, and life management. Among the different components of the e-health system, one recurring question is where exactly what technology should be used. This is an aspect of designing the system and will be considered in designing the system from this research for the specific context of Saudi Arabia. COMMODITY12 can be considered as a model for use in this present research for suitable adaptation to Saudi requirements, which may mean some modifications in the list of design requirements provided earlier.

A distributed information infrastructure was proposed by Su and Wu (2011). This system uses an intelligent agent paradigm. The use of this paradigm facilitates rapid alerts of abnormal conditions to the responsible care provider to offer distance medical advice. It can also monitor health conditions. Issues of interoperability, scalability and openness in heterogeneous e-health environments were solved using a FIPA2000 standard-compliant agent development platform called Java Agent DEvelopment Framework (JADE). The possible information side and management issues discussed in this paper will be useful when designing the mobile-enabled e-health system for the self-management of diabetes patients in Saudi Arabia. The issues arising from the findings of this paper are how critical situations can be alerted to the physician or the hospital and the addressing of information and management for interoperability, scalability, and openness. The findings of this research did not cover the points highlighted in the paper; however, they have been considered in the list of design requirements through patient–doctor communication, interaction with local diabetics' groups, integrating various components, cloud storage and care standards.

The education of patients through the coaching method was considered above. Another very interesting method that may motivate patients to seek information is the gaming experience. Educating patients about their chronic problems and how to manage them using games in e-health helps to achieve better compliance with prescribed interventions and positive health behaviour (Sardi et al., 2017). In this research, increasing awareness and knowledge of patients about diabetes and interventions has been included in the list of e-health system design requirements. However, there is no guarantee that they will see the information uploads on the sites, as they may feel bored by seeing the same things time and again. Gaming may be a novel way to increase patients' knowledge without feeling bored. New games can be uploaded frequently to engage them continuously. However, this is not considered among the list of design requirements due to the disadvantages identified here.

Patient empowerment in access to health information and the freedom to decide on which tools to use has been researched in many studies. In their work, Alpay et al. (2011) examine empowerment as the development of self-management tools. Patient empowerment is an important mechanism of e-health self-management, communication, education and health literacy, and information (Johnson et al., 2012), along with self-care, decision aids and contact with fellow patients. All components require the skills of both patients and physicians. In this research, patients' empowerment is ensured from data obtained in the focus group as well as the surveys. Empowerment consists of communication, education and health literacy, information, self-care, decision aids and contact with fellow patients. Care empowerment was a top priority in the findings of effective self-management of diabetes in Alpay et al.'s (2011) paper on the required skills for effective self-management tools. Empowerment should not be misunderstood as a patient deciding to reject intervention prescriptions and doing what he/she likes. In the model proposed in this research, empowerment is initially restricted to access to information. Then, as patients become educated enough to make rational decisions based on the information accessed, they are gradually empowered to decide on the course of action based on medical advice. The hope is that they will decide in favour of following medical advice. Patient empowerment has been incorporated into the list of design requirements.

From empowerment, the related aspect of self-management arises. The empowerment of patients is key to increasing self-management. This element will be built into the model for the Saudi system. Health-related self-management systems that leverage a service-oriented architecture were discussed by Hsieh et al. (2012). In this research, the level of achievement of empowerment leading to self-management will be assessed during monitoring and periodical reviews of the designed system.

E-health is increasing in popularity with attendant changes in clinical practice and healthcare systems. However, there is no clarity on how it can be leveraged to achieve the promised benefits of e-health technologies. Innovations in technology and applications enable evidence-based clinical decision-making with the involvement of patients, which also improves care quality and efficiency and engages individuals in clinical decision-making. Empowering the different actors in the system adequately to play their roles is important (Wicks et al., 2014). In the case of Saudi Arabia, leveraging e-health is to be directed towards a reduction in the prevalence of diabetes so that the national productivity becomes high, which is comparable with the national productivity of developed nations. The reduction of the prevalence of diabetes is possible when large numbers of diabetic patients achieve the desired levels of reductions in their blood sugar levels. In this research, the survey results of 100 participants have shown that significant reductions in blood sugar levels have been achieved even in the present system of disease management. When the proposed m-health system is implemented, even better results can be expected.

To address the problem of accessibility to quality care for rural and remote areas and elderly diabetes patients, Beula Devamalar et al. (2009) designed a medical network based on the then most advanced medical kiosk to address the problems of providing preventive and diagnostic healthcare. The model developed by the authors was a web-centric diabetic expert system kiosk like a bank automated teller machine. These findings lead to the question of whether separate e-health systems are required for women and the elderly in Saudi Arabia. The results of this study show that both are important in the Saudi context. This aspect has been considered in the list of design requirements in the e-health model.

Benharref and Serhani (2013) combine a cloud service-oriented architecture and wireless biosensors for e-health monitoring. Their framework was aimed at collecting real-time patient data, undertaking appropriate non-invasive monitoring, and suggesting changes in medical and/or lifestyle engagements as required and appropriate and to achieve the seamless integration of different technologies, applications, and services. Mobile technologies are used for the smooth collection and communication of vital data from patients' wearable biosensors. The problems of limited capabilities and power drainage and intermittent network disruptions are also considered. When any of these happen, data stored in the cloud is routed through service-oriented architecture (SOA) for easy access by physicians, paramedics, or any other authorised persons. Preliminary tests showed that the model had promise. The use of cloud, IoT and other modern and emerging technologies needs to be carefully evaluated before they are implemented on a wide scale. Using such a system at present will increase complications and hence are not considered in the design requirements for this research.

A pay-as-you-use model of a cloud-based e-health system was proposed by AbuKhousa et al. (2012) to cut costs to the industry. However, if the cost of this system is high for patients, then the already low affordability for poor patients will worsen. The authors discussed the limitations of current healthcare systems as a lack of laws and regulations enforcing the use and protection of data from privacy invasions, fragmented health IT data, the high cost of implementation and maintenance and a lack of cloud-based e-health designs and standards. The benefits of a good e-health system include better quality patient care, lower costs, no resource scarcity problem, research, national security, strategic planning and financial management facilitation of clinical trials, and the formation of registries. The centralisation of healthcare data involves risks of data security, data losses and system availability. There are also technical and other challenges. As healthcare for Saudi citizens is free in the country, this issue is not relevant in the present case.

The procedure to design and test an e-health model for diabetes was described by Bellei et al. (2020). The purpose was to monitor the relationship among treatment factors of Type 1 diabetes mellitus. The authors followed the procedure as described here. Based on a literature review and a commercial search, ideas of the system requirements were obtained. Using the requirements, a prototype, and an online survey for feedback on the prototype was done. Then, a website and mobile app were built. A preliminary test with four patients, an online experiment for satisfaction assessment with 97 patients, and an online assessment by nine health professionals provided encouraging results regarding the framework. Suggestions for improvements from the participants were considered for building the actual system from the prototype. A slightly different process is being adopted in this research. Based on the literature review and the results of survey and focus group, the design requirements for an efficient and effective e-health model have been listed.

In connection with the use of IT in healthcare, six aims issued by the Institute of Medicine were considered (Tang & Lansky, 2005). The six aims of providing care are safe, effective, patient-centred, timely, efficient, and equitable. One of the reasons for the rapidly increasing IT-based healthcare systems already prevalent in many countries is the belief that the use of IT will make it easier to achieve these six aims. Many patients and healthcare professionals have expressed a high degree of satisfaction with such systems. The same points were considered by Bashshur et al. (2009) when a diverse group of researchers supported the need for telemedicine as an application of IT to healthcare. Satisfaction with the e-health system developed in this research for the Saudi Arabia context and the findings of this study are important variables for future research.

In Germany, e-health cards were distributed to nearly 80 million patients and e-health became mandatory for all healthcare institutions to implement. A survey was conducted by Ernstmann et al. (2009) to examine the factors contributing to the acceptance of the system by primary care physicians. The results showed that they supported e-health cards for the reduction in medical errors and improved communication between caregivers and patients. However, they did not consider a substantial role for them in developing the e-health system. One key aspect to note is that e-health cards are very convenient. When the model from this study is implemented in the country, the Saudi government can consider the introduction of e-health cards for its citizens, which can also be used for availing various benefits declared by the government.

Cybercriminals and attackers tend to exploit the vulnerabilities associated with ICTs. When this happens, patient healthcare data are breached. Some security attacks on e-health systems were reviewed by Zeadally et al. (2016). Based on the findings, they proposed some solutions to mitigate them. The need to incorporate security measures in the system design stage itself was highlighted by the authors. The same approach will be utilised in the designing of the model in this research.

Many state-of-the-art technologies, including cloud computing, SOA, homecare telemedicine technologies, e-PHR, e-Prescribing, e-referral and e-learning in the healthcare environment, were combined into an integrated e-health platform. The requirements included care dimensions like home care, the prescription of medicines, referrals for diagnosis, and payment and reimbursement arrangements. With these requirements, all the stakeholders are involved. Social, economic, industrial and research communities will benefit from this integrated system (Themistocleous et al., 2013). In the case of Saudi Arabia, there may be limitations in applying all these technologies all at once. It may be preferable to distribute increasing levels and applications of technologies to different stages and evaluations.

Healthcare problems in Canada include long waiting times, lack of access, the high cost of delivery and medical errors. Bliemel and Hassanein (2004) used a business process reengineering (BPR) framework to evaluate its suitability for solving these problems. Sometimes, the achievement of radical performance improvements is possible if a clean slate approach is used for replacing all outdated concepts with new ones. The authors explained the BPR framework in terms of which BPR principles are used, who the participants are in the process, what the enabling technologies are, and the implementation issues of concern for each of the four problems. To improve Saudi Arabia's e-health problems, first, the problems have to be identified and then how BPR can be used to solve the problems needs to be assessed. If BPR can solve the problems, e-health modelling can be done on that basis. This is the next stage for this research.

The aim of the research by Wakefield et al. (2011) was to evaluate the efficacy of a nurse-managed home tele-health interventions to improve outcomes in veterans with comorbid diabetes and hypertension. From the results of a randomised control trial, it was noted that home tele-health, as an innovative and pragmatic approach, improved through the earlier detection of interventions requiring critical clinical symptoms. It also facilitated the continual transmission of education and advice to the patient, and nurse surveillance, leading to an improvement in clinical outcomes for patients who had diabetes with comorbidities. Home tele-health is almost synonymous with m-health as it facilitates home care.

Tele-health technology was proven to be an effective and efficient way to provide diabetic care to patients in rural areas and other inaccessible areas. Details of results obtained by Ciemins et al. (2011) for each aspect of diabetic care are given and discussed. Increased blood glucose level reporting and increased diet control adherence were noted for tele-health compared to face-to-face methods. However, it must be noted that face-to-face is a preferable option for many and the aim of any other method like tele-health, e-health and m-health is to be as close to the face-to-face method as possible through better management of the system. This is the yardstick that has been used for modelling in this research, with the aim that the designed model will be as close to face-to-face as possible. However, there will be trade-offs in achieving this aim (e.g., lack of interpersonal relationship with the physician).

Monitoring is required for optimal disease management of a patient with inflammatory bowel disease. E-health technologies are promising tools for this. Bossuyt et al. (2017) found the adoption of e-health faces challenges like having the necessary laws in place to protect the patient and the need to validate current e-health modes. To what extent Saudi laws and regulations support e-health is a matter to be examined when designing a e-health model.

In the case of asthma, Holtz and Whitten (2009) tested an innovative model for tracking asthma symptoms and early intervention in the case of four patients. The method was found to be feasible and manageable. However, the generalisation from just four samples may not be valid. Some regular patients will always send data to the system for early intervention, while some others may fear the loss of privacy and the use of their personal data for other purposes and therefore may hesitate to use an application on their smartphone. Therefore, the authors suggest that their model should be tested in other countries. It is also unknown whether this model can be extended to other chronic problems. The differential positive and negative perceptions and attitudes about e-health lead to the acceptance or rejection of the system by the patients. The success of e-health implementation depends on the very low number of negatively perceiving patients. Data need to be collected when the designed system is trialled.

Patients affected by T1D need to actively participate in their treatment as they are inevitably responsible for their day-to-day care. Mobile phones can be used for this purpose. Kollmann et al. (2007) used a before-after study to examine how well Austrian T1D patients actively participated in their treatment. A software called Diab-Memory based on Java 2 Mobile Edition was developed for the intervention. The data obtained from the trial were analysed for statistics and trends and supplied to the patients. The system was evaluated using this method. The use of this application was received well by the trial participants. Metabolic control of HB1c was obtained but blood sugar did not decrease appreciably. The authors have planned improvements to the mobile application for the control of blood sugar levels. Process ownership or responsibility for actions is a useful point for convincing patients with negative attitudes about e-health. In this way, the solution to this problem raised above has been addressed.

Hassen et al. (2019) propose an e-health system to monitor health conditions based on the IoT and fog computing. MySignals HW V2 platform and an Android app that plays the role of fog server constituted the system components. This enabled the collection of physiological parameters and general health parameters from elderly patients at scheduled times. This application allowed the elderly and their families to follow their health conditions and communicate with healthcare providers (both administrators and doctors) leading to clinical advice, recommendations, notifications, and alerts when the values show critical trends. Most users perceived the system to be useful and easy to use and learn. These advantages of m-health prompt us to look at the implementation of e-health in the form of m-health in Saudi Arabia, which has been included in the design requirements in this research.

6.3 Possible problems of implementing an e-health self-management model for Saudi diabetic patients.

There is much that needs to be considered when an e-health model is designed. The results of this research are discussed in previous sections. However, there are other problems arising from quantitative studies. These are discussed in this section.

The most important problem concerning Saudi diabetes patients was that only very few hospitals were e-health ready. Additionally, many patients did not follow the intervention advice on diet control and physical activities. There is a need to motivate them to practice all the prescriptions on blood glucose monitoring, insulin injections, diet control and physical activity and to report all the data to the database. Over two-thirds of the patients did not follow their diet and physical activity prescriptions. One positive aspect is that the patients generally had positive attitudes and perceptions about e-health in diabetes self-management at home. This may facilitate motivating the patients to accept the e-health system but not to follow prescriptions correctly.

The experience of patients was positively correlated with attitude, higher education levels and lower incomes, which suggests that these patients can be motivated relatively easily. Therefore, it is expected that these types of patients should be the first target for design testing and implementation. This targeting has already been done in the design requirements outlined previously.

Even when all precautions are taken, the designed e-health model for self-management of Saudi diabetes patients can go wrong. One factor may be the influence of Islamic culture. Some opposition from religious leaders is possible if they perceive certain actions to be against Sharia. Personal discussions with them may convince them ultimately that there is nothing against Sharia in the model or its implementation.

Overall, most of the points arising from the review conducted in this section have been considered and incorporated into the design requirements listed previously. Some suggestions derivable from some research cannot be considered in the Saudi context due to the addition of complications making it difficult to manage the system at least in the initial stages.

The extent to which the research question/aims and objectives have been achieved in this research is analysed now in reverse order.

6.4 Achievement of research objectives

This thesis had four research objectives. Each of these are listed below, along with a description of how they were achieved.

1. To understand the current issues and challenges of e-health systems and requirements from the literature and survey findings.

The design requirements have been achieved from the literature and the survey responses findings.

2. To identify and analyse design requirements from stakeholders' perspectives (patients, healthcare practitioners and e-health experts) in Saudi Arabia.

This objective required me to provide explanatory support for identifying modelling requirements from a stakeholder point of view. In this research, I identified the most-cited models of e-health and requirements engineering and based on this, I developed a list of research questions. The focus group then evaluated the selected models and reported their findings.

3. To provide design requirements and parameters for e-health-based personalised diabetes management in Saudi hospitals.

For this research objective, I identified and understood how e-health systems are being developed. Also, I understand that successful techniques are implemented in the real world.

4. To enhance and evaluate the awareness and understanding of e-health design requirements, which could benefit e-health developers and academics.

Both the studies – quantitative and focus group – were conducted with health and requirements engineering experts or users. So that the study outcome would be useful for the selected hospitals and based on the results, improvements can be made if required for the overall health environment in Saudi Arabia.

6.5 Research aims.

This research aimed to identify the factors related to e-health and the critical evaluation of existing e-health tools, techniques, models, and frameworks. This research also evaluated e-health factors and techniques quantitatively and through a focus group.

The design requirements have been identified as target group profiling, variables of modelling, technologies to apply, m-health, and outcomes in terms of prevalence reduction over the years. The results of the literature review, survey and focus group discussion helped to identify them with some inputs from quantitative data.

6.6 The expected impact of diabetes reduction among the Saudi population

The first way to have an impact on diabetes treatment and reduction is to get as many diabetes patients as possible to register in the e-health system. The assumptions used to establish the expected impact of diabetes reduction among the Saudi population are listed below. All costs are in US dollars (USD).

Cost per patient = $2,000–3,000

Total adult Saudi population (WHO, 2019) = 20.77 million

Total number of diabetic adults in Saudi Arabia in 2019 = 3.85 million adults

The population of children and adolescents 5–19 years (WHO, 2019) = about 12 million

Diabetes among children and adolescents = 355 per 100,000 population of 5–19 years = 4,260

Let us leave out people with obesity becoming diabetic and any newly diagnosed cases from this estimation.

Mean blood glucose level before intervention: 14.267 mmol/L

Mean blood glucose level after intervention: 7.933 mmol/L (7.8 mmol/L is ideal)

Reduction: 6.334 mmol/L = 44.4%

The mean duration is 9.68 years – say 10 years.

So, let us assume that the blood glucose level of diabetic patients is reduced to the ideal level of 7.8 mmol/L or less in 10 years.

Based on the above data, a large proportion of the adult population of 3.85 million can become non-diabetic in 10 years.

A large proportion of the 4,260 million children and adolescents will become non-diabetic in 5 years. However, this can be ignored as the number is too small to be included.

In the status, the total adult population is 20.77 million, out of which approximately 3.85 million will become non-diabetic. So, the decrease in prevalence is 16 percent.

But with the new e-health model, there is better management of diabetes, and we need to target this reduction to be achieved in five years. As no work has been found on possible reductions by self-management, this is data to be generated during the selection of the best model, the pilot tests, and being rechecked by monitoring during implementation.

Since the cost per patient for treatment of diabetes is about $2,500 on average ($2,000–$3,000), the total cost saving by the patients achieved in five years with the new model will be $92.4 million. This is the economic impact of implementing the new model.

6.7 Summary

This research aims to identify the design and process engineering requirements so that an efficient and effective e-health-based personalised diabetes management model can be created and implemented. To this end, this chapter discussed the modelling requirements including the importance of alignment between information systems and e-health and evaluated the factors among e-health experts.

Chapter 7 – Conclusion

7.1 Introduction

The findings of the research were discussed in Chapter 6 of this thesis. This chapter summarises the findings reported and discussed in the earlier chapters and derives conclusions from them. It also examines the consequences of this study, the continuing challenges in the subject and the potential for future research.

Moreover, the usefulness of information and communication technology has been demonstrated in a variety of fields. In healthcare, it can help to enhance care quality for a better outcome at a reduced cost for both the patient and the government. In this research, an e-health modelling system for the self-management of diabetes has been developed and further testing and evaluation for large-scale implementation in Saudi Arabia are envisaged.

7.2 Research aim and questions

There were five research questions in this thesis: one main question and four additional questions. The main research question is as follows.

> What are the design requirements modelling for personalised diabetes management systems in Saudi Arabia?

The four research questions are as follows-

1. What is the current situation of health in Saudi Arabia? (RQ1)
2. What are the current design requirements, models, and theories in the literature? (RQ2)
3. What is the role of design requirement engineering and process modelling in the context of health improvement? (RQ3)
4. What is the role of stakeholders in identifying design requirements modelling for personalised diabetes management systems in Saudi Arabia? (RQ4)

The objectives were-

1. To understand the current issues and challenges of e-health systems and requirements for the literature and survey findings.

2. To identify and analyse design requirements from stakeholders' perspectives (patients, healthcare practitioners and e-health experts) in Saudi Arabia.
3. To provide design requirements and parameters for e-health-based personalised diabetes management in Saudi hospitals.
4. To enhance and evaluate the awareness and understanding of e-health design requirements, which could benefit e-health developers and academics.

The aim of the study was to seek ways to reduce the current high prevalence of diabetes in Saudi Arabia in a cost-effective way. This research sought to achieve this aim by identifying the design requirements and process engineering requirements for an e-health system to enable personalised diabetes management, using them for modelling and implementation in King Abdulaziz Medical City, Jeddah. This section delivers a summary of this research, as shown in Figure 7.1.

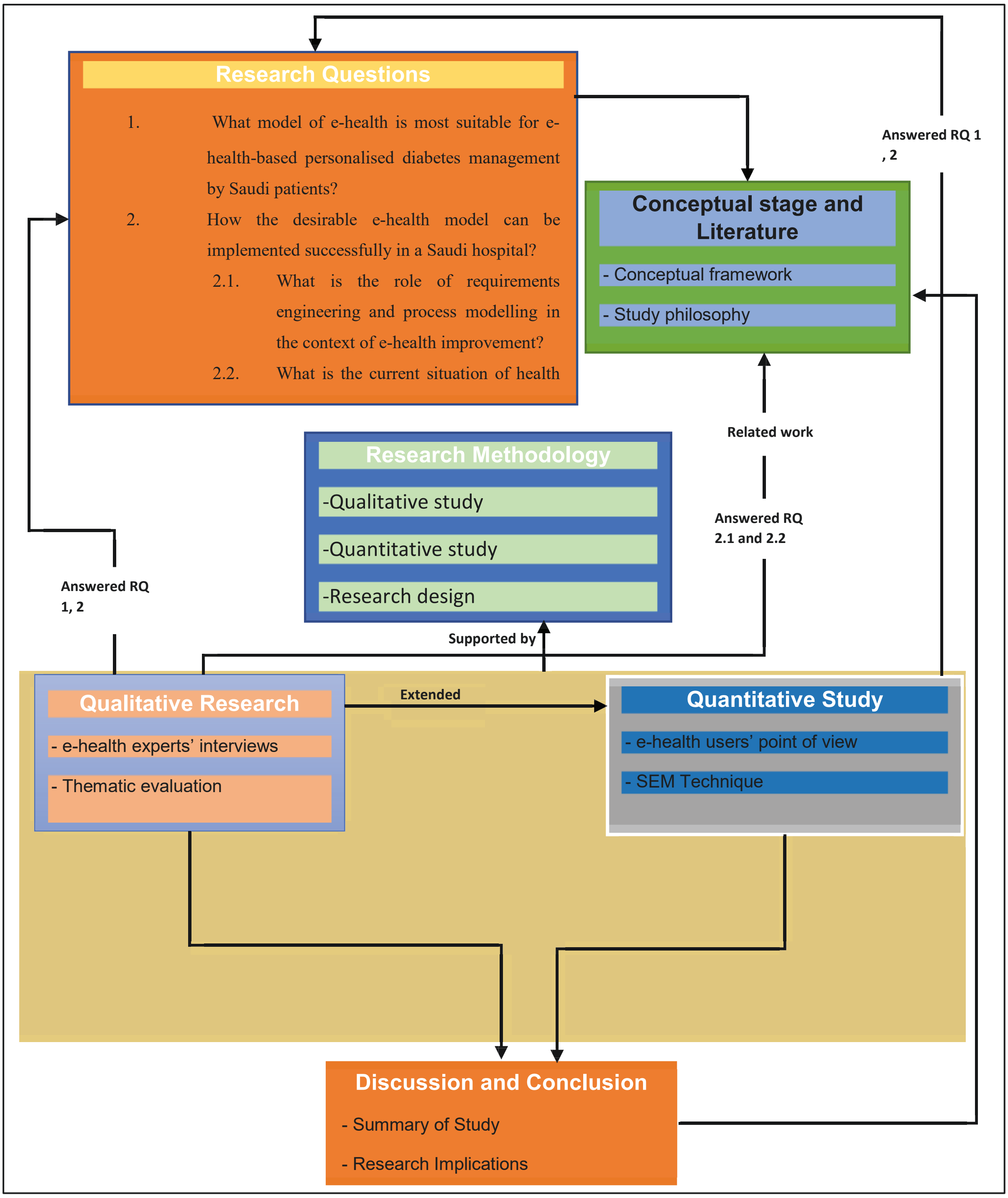

Figure 7.1: Conclusions across all study questions and contributions

7.3 Research methods adopted-

To achieve the aim of finding ways to reduce the current high prevalence of diabetes in Saudi Arabia in a cost-effective way, there were six components to the research:

1. A focus group session with stakeholders about personalised diabetic care and management process. This was aimed at identifying the inputs for modelling the e-

health requirements in this aspect of care. This session resulted in the identification of processes and systems requirements and the preparation of a list of design requirements and model options in which literature input and survey results were also used.

2. A quantitative questionnaire survey of the diabetic patients in the Jeddah area to identify the diabetes patients currently using e-health-based personalised diabetes management. This enabled me to understand the scope of extending the benefits of e-health-based self-management of diabetes to a substantially large number of patients for a significant reduction from its high prevalence.
3. A quantitative survey of diabetic patients on the change in blood sugar levels achieved due to interventions of medication, diet, and exercise. This enabled me to evaluate the scope of reduction in the prevalence of diabetes and the duration required for a target reduction in prevalence.
4. Estimates of the possible impact on prevalence and costs was also prepared.
5. The design options will be pilot tested and the most suitable model for implementation in Saudi Arabia will be selected.
6. The final step is identifying system requirements for King Abdulaziz Medical City, Jeddah through the collection of data on the outcomes, monitoring and the need for any further improvement for country-wide application.

The quantitative analyses were conducted using SPSS, which has proven to be consistently reliable in a variety of statistical analysis projects. A correlation analysis was also conducted and found the following results:

a. There is a positive and significant correlation between the experience with e-health system scores and the attitude about e-health system score.
b. There is a positive and significant correlation between the experience with e-health system score and the participant having higher education like diploma, degree or higher levels.
c. There is a positive and significant correlation between the attitude about the e-health system score and the participant having a low monthly income (8,000 riyals or less).

d. There is a significant reduction in blood sugar levels due to interventions of medication, diet and exercise in that order of reduction. Also, reduction in blood sugar levels was higher in the case of females and those over 50 years of age.

These have been further discussed and elaborated on in Chapter 5.

For the qualitative data from the focus group, the thematic analysis proposed by Braun et al. (2014) was adopted. The objective of the focus group was to provide explanatory support for identifying modelling requirements from the stakeholder's point of view. In this focus group, four each of diabetes patients, doctors and nurses, IT specialists and close relatives and friends participated. Questions were designed to be answered by specific stakeholder groups. 14 themes were derived from the thematic analysis of the focus group discussion:

1. Predisposing factors of diabetes
2. The need for diabetes management
3. Aim of diabetes control
4. Primary interventions
5. Achievement of control
6. Supports
7. When something goes wrong
8. Resolving issues going wrong
9. Advanced methods of intervention
10. New methods of intervention
11. Using e-health for in-home self-management
12. Integration of m-health with e-health for self-management
13. Identifying variables of a comprehensive e-health self-care system
14. Likely future developments

These themes are further explored in Chapter 6, which also highlights the different perspectives of all the stakeholders involved.

7.4 Key findings

Through quantitative and qualitative methods, data were obtained for addressing the research questions. In this regard, patients, local healthcare systems, local community health workers, centralised healthcare systems and community networks were identified as the key levels for research.

Based on the results of the surveys, the design requirements for modelling an e-health system for the self-management of diabetes in Saudi Arabia are repeated below for convenience.

1. Patients: Targeted customised intervention.

Variables to consider in modelling are-

a) Demographic profile: Diabetes is more among women of all ages, especially 25–50 years of age, in secondary school or with a degree, unemployed, government employee and with monthly income lower than 15,000 SAR. The target group for customisation needs to be done on this basis. Also, people of an older age and women during menstrual cycles or while pregnant need to be considered as specific targets.

b) Diabetes profile: Requiring special attention in customisation and m-health. T1D for over five years. Higher stress is to be placed on the strict following of diet and physical activity recommendations.

c) Interventions: Medications, diet, and exercise. In the survey results, a reduction in blood sugar levels was noted in this order of interventions; however, the regression equation was possible based on exercise only. However, to avoid the risks of focusing on only one intervention, all three interventions will be included in the e-health model.

2. Patients' homes facilitating self-management of diabetes.

3. Hospitals: Self-care management systems attached to the nearest diabetes care speciality hospital and ultimately to the Ministry of Health database. Patient–doctor communication is to be facilitated using smartphone applications like WhatsApp, SMS, et cetera.

4. Healthcare systems.

The requirements are-

a) Increase registration of patients for hospital-based e-health self-care management programmes.

b) Mobile facilitated e-health (m-health) with cloud storage of data with adequate security steps may be ideal. The electronic health records of patients with visibility for both the concerned patient and the doctor and a knowledge base for evaluating the latest evidence on diabetes management can be linked to this communication system so that the doctor can advise based on this information.

c) Variables of customised e-health self-care programme: Regular blood glucose monitoring, insulin injections, daily food intake and physical activity programme as per the advice and enter into the e-health system on the day itself. Enter any other chronic health problems in the system. Contact local healthcare systems for acute conditions and get treated. Alert the healthcare systems on any serious problems for urgent attention.

d) Desirable: Use local healthcare centres and community health workers for maximum benefit. Patients are motivated to become members of the diabetes community group of the area and participate in the discussions and interactions sharing experiences and learning from others. Social group workers need to be trained appropriately for handling varying and critical situations in their areas.

e) Scope for introducing wearable devices to be examined and introduced as and when required and connected to the m-health system.

f) Improvements in the above design based on monitoring outcomes in terms of the design variables and periodical reviews.

Four design models were derived from the above list:

1) Web-based, traditional data storage base
2) Web-based, cloud storage of data
3) Mobile-based, traditional data storage base
4) Mobile-based, cloud storage of data

These models can be pilot tested with small samples and the most desirable one will be selected for validation at King Abdulaziz Medical City, Jeddah. The validated model with any required improvements can be transferred to the Ministry of Health, Saudi Arabia for gradual implementation in the whole country with continuous monitoring and review for any further improvement required.

The calculations shown in Chapter 6 suggest a definite scope for reducing the diabetes prevalence rate by 16 percent within five years instead of the currently possible reduction in 10 years with the implementation of the new finalised version of the e-health self-management system for Saudi diabetic patients. This would bring with it possible cost savings of USD 92.4 million.

A possible final e-health model, based on the above four models for the research context is proposed in Figure 7.2.

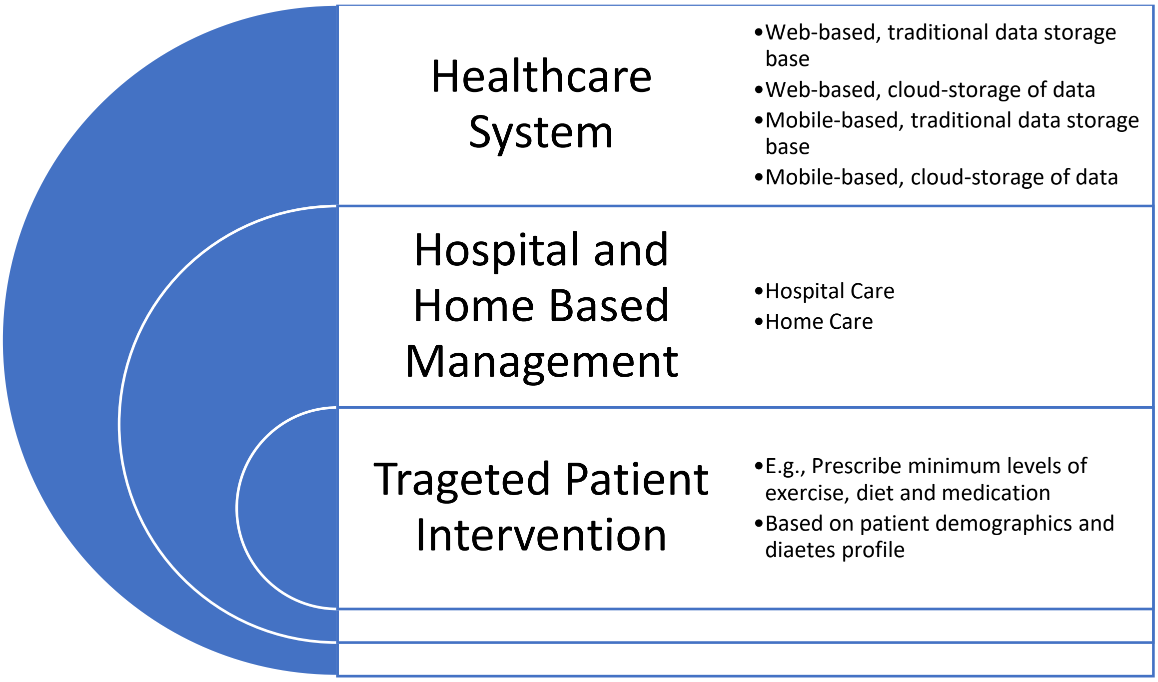

Figure 7.2: Proposed e-health system model for Saudi diabetes patients

The model consists of three main components: healthcare system, hospital and home-based management, and targeted patient interventions. This model is only a model related to the principles of model designing, as it can be noted that many essential design requirements identified in this study are missing in the model.

Furthermore, a tentative framework (Figure 7.3) in a hierarchical model with all structured requirements to help future system designers in understanding requirements better is proposed below.

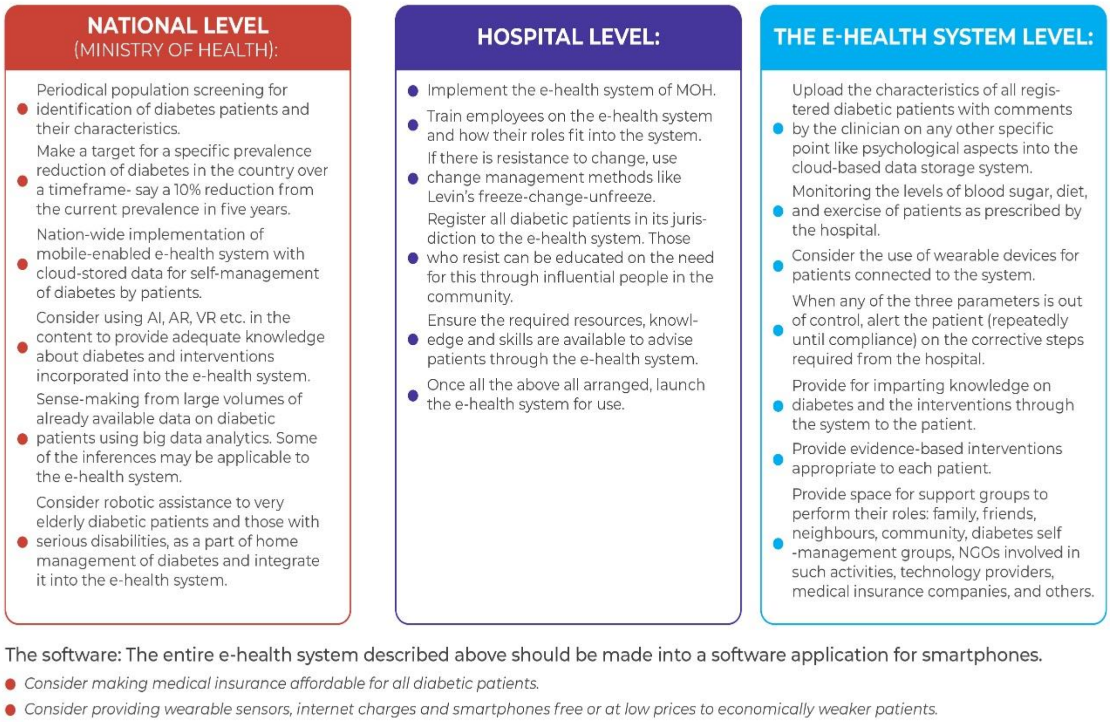

Figure 7.3: Framework of e-health structural requirements in Saudi Arabia

National level (Ministry of Health):

- Periodical population screening for identification of diabetes patients and their characteristics.

- Make a target for a specific prevalence reduction of diabetes in the country over a timeframe- say a 10% reduction from the current prevalence in five years.

- Nation-wide implementation of mobile-enabled e-health system with cloud-stored data for self-management of diabetes by patients.

- Consider using AI, AR, VR etc. in the content to provide adequate knowledge about diabetes and interventions incorporated into the e-health system.

- Sense-making from large volumes of already available data on diabetic patients using big data analytics. Some of the inferences may be applicable to the e-health system.

- Consider robotic assistance to very elderly diabetic patients and those with serious disabilities, as a part of home management of diabetes and integrate it into the e-health system.

Hospital level:

- Implement the e-health system of MOH.
- Train employees on the e-health system and how their roles fit into the system.
- If there is resistance to change, use change management methods like Levin's freeze-change-unfreeze.
- Register all diabetic patients in its jurisdiction to the e-health system. Those who resist can be educated on the need for this through influential people in the community.
- Ensure the required resources, knowledge and skills are available to advise patients through the e-health system.
- Once all the above all arranged, launch the e-health system for use.

The e-health system level:

- Upload the characteristics of all registered diabetic patients with comments by the clinician on any other specific point like psychological aspects into the cloud-based data storage system.
- Monitoring the levels of blood sugar, diet, and exercise of patients as prescribed by the hospital.
- Consider the use of wearable devices for patients connected to the system.
- When any of the three parameters is out of control, alert the patient (repeatedly until compliance) on the corrective steps required from the hospital.
- Provide for imparting knowledge on diabetes and the interventions through the system to the patient.

- Provide evidence-based interventions appropriate to each patient.
- Provide space for support groups to perform their roles: family, friends, neighbours, community, diabetes self-management groups, NGOs involved in such activities, technology providers, medical insurance companies, and others.

The software: The entire e-health system described above should be made into a software application for smartphones.

- Consider making medical insurance affordable for all diabetic patients.
- Consider providing wearable sensors, internet charges and smartphones free or at low prices to economically weaker patients.

7.5 Recommendations and Future Research

The usefulness of e-health initiatives for diabetes care has been of interest to many scholars (e.g., Fatehi et al., 2017). In the context of Saudi Arabia, it was found that very few hospitals are currently equipped with the facilities to make e-health a viable alternative for patients. The patients were also found not to comply with the intervention and advice regarding their diet control and physical activities to arrest and regulate their diabetes and sugar levels. Hence, there is a need to motivate patients to practice all the recommendations including blood glucose monitoring, insulin injections, diet control and physical activity and report all data to the database. Research showed that over two-thirds of the patients did not follow the diet and physical activity recommendations given to them. However, one positive aspect that was highlighted was that the patients reported having a positive attitude and perception of e-health in diabetes self-management at home. This may facilitate motivating the patients to accept the e-health system. More research on what motivates or prevents people from adopting e-health systems needs to be done in the Saudi cultural context.

The findings showed that there are a variety of stakeholders involved in such an ecosystem. It is therefore imperative to ensure smooth coordination and an improvement in the outreach of public health campaigns. The findings thus far have highlighted the demographic groups to be focused on for designing and implementing targeted interventions to tackle diabetes in Saudi Arabia. The experience of patients was found as being positively correlated with attitude, higher education levels and lower incomes. It may be inferred, therefore, that these patients can be motivated relatively easily. Therefore, these types of patients should be the first target for design testing and implementation.

It must be mentioned here that the designed e-health model for self-management of Saudi diabetes patients can go wrong, even if every precaution is taken. One of the reasons for this may be the strong influence of Islamic culture in the country. Some opposition from religious leaders is possible if they perceive certain actions to be against Sharia. This may be combatted through personal discussions with them to explain to them that there is nothing against Sharia in the model or its implementation. Hence, taking such cultural considerations into account, the design requirements, and parameters for e-health-based personalised diabetes management in a Saudi hospital have been identified in this thesis. Since this research aimed to identify design and process engineering requirements, this thesis identified the modelling requirements.

The importance of this work cannot be overstated. Given the rise in the number of diabetic patients in Saudi Arabia, the healthcare system faces immense stress and challenges. In addition to this, the recent Covid-19 pandemic has highlighted the need and value of e-health in assisting patients without physical contact. In this context, therefore, this research is a valuable first step in determining how such interventions may be designed to ensure their success.

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APPENDIX A

Survey Questionnaire for Diabetes Patients in Saudi Arabia

Project brief.

Informed consent.

Please proceed to answer the survey questionnaire below.

A. Demographic factors

For the following items, please select the answer that applies to you-

1. Gender- Male/Female

2. Age-
<25 Years
25-50 Years
>50 Years

3. Educational qualifications-
a) High school or lower
b) Degree
c) Post-graduate and above
d) Special training-Please explain the special training briefly.

4. Employment status-
a) Unemployed
b) Self-employed
c) Working in a private company
d) Working in a public company
e) Saudi government employee

5. Monthly Income Level-
a) <8000 SAR
b) 8000-15000 SAR
c) >15000 SAR

B. Status as a diabetes patient

1. How long you are a diabetic patient? Please tick what applies to you.
a) <1 Year Recent
b) 1-5 Years
c) >5 Years Long term

2. Are you a Type 1 or a Type 2 diabetic patient? Please tick what applies to you.
a) Type 1 (insulin-dependent)
b) Type 2 (blood sugar level)

C. Treatment against diabetes as an outpatient of the hospital-

For the following statements, please tick the option applicable to your case-

1) I have been prescribed medical treatment for my diabetes problem- Yes/No
2) I am following the prescribed medications strictly- Yes/No
3) I have also been prescribed diet regulation to control diabetes- Yes/No
4) I am following the prescribed diet regulation strictly- Yes/No
5) I have been prescribed daily exercise to keep my diabetes under control- Yes/No
6) I am following the prescribed daily exercise programme strictly- Yes/No
7) After initial outpatient consultations in the hospital, I am now in my home under self-care- Yes/No
8) My hospital has an e-health-based self-care management system for diabetes patients- Yes/No
9) I am a registered user of this e-health system- Yes/No
10) My self-care programme has regular blood glucose monitoring at home- Yes/No
11) I monitor my blood glucose at home- Regularly as prescribed/Monitor irregularly/Not at all
12) I report my blood glucose levels to my hospital through the e-health system- Whenever measured/Only when any abnormal level is seen/Not at all
13) My self-care programme includes insulin injections as prescribed by my physician- Yes/No
14) I do the insulin injections- Regularly as prescribed/Monitor irregularly/Not at all
15) I report my insulin injection details to my hospital through the e-health system- - Whenever measured/Only when any abnormal level is seen/Not at all
16) My self-care programme has a daily diet regulation programme. Yes/No
17) I follow daily diet regulations- Regularly as prescribed/Follow irregularly/Not at all
18) My self-care programme has a daily exercise programme- Yes/No
19) I do exercise- regularly as prescribed/Follow irregularly/Not at all
20) I report any abnormality in my health conditions through the hospital e-health system- Whenever any such incidence occurs/Only when I am unable to suffer it/Not at all

D. Experience with e-health-based self-management system for diabetes- Please rate the following statements as per 1- Strongly disagree; 2-Disagree; 3- No opinion; 4- Agree; 5- Strongly agree.
1) I find the system useful to control diabetes.
2) This system is effective
3) My need to visit the hospital has reduced.
4) My cost of treatment has been reduced with e-health system self-management

5) My overall experience is good concerning this self-management system

E. Attitude about the e-health-based self-management system for diabetes patients- Please rate the following statements as per 1- Strongly disagree; 2-Disagree; 3- No opinion; 4- Agree; 5- Strongly agree.

1) I feel this system is good for diabetes patients.
2) I see that even remotely located diabetes patients are benefitted from this.
3) I feel the system is efficient and effective.
4) I will express my favourable opinion to my friends.
5) I will recommend an e-health based self-management system for diabetes to other diabetes patients.

Thank you for your kind participation.

APPENDIX B

Focus Group Questions

1. Episode- let us assume, the patient reported high sugar readings thrice during the last three, monthly monitoring. He was not on insulin, but on diet management only till then. There was no advice from the hospital on these readings. He knows something needs to be done immediately. If he is far away from the hospital, what is the solution?

2. Each diabetic patient may please describe his/her experience in managing his/her diabetes at home. Was there any difficulty? How did you solve it?

3. Each friend or relative may please describe the hardships they were put on when the patient was in some problem. Describe the problem and how you were involved and how was it solved.

4. Was there a possibility that e-health would have helped in these situations?

5. e-health with personalised management at home- what are your ideas about it?

6. Do you feel e-health should be based at home with only essential visits to hospitals? How can visits to the hospital be reduced if the patient does not have adequate knowledge and does not understand his condition well?

7. What is the scope of integrating mobile phones in e-health for personalised care?

8. Thinking of e-health for personalised care, what elements need to be included in such a system?

9. How do these elements help personalised care in e-health management of diabetes?

10. Anyone wants to add any more?

11. Concluding the session by summarising the proceedings.

APPENDIX C

Invitation Letter

UTS UNIVERSITY OF TECHNOLOGY SYDNEY

INVITATION LETTER (Stage 1)

Design and Process Requirements of E-health Models for Personalised Care Management: Focus on Diabetes in Saudi Arabia

Dear participant

My name is Fuhid Alanazi and I am a student at the University of Technology, Sydney.

I am conducting research on designing the most suitable an ehealth application model for personalised diabetes care and management and would welcome your assistance. The research will involve filling out a brief questioner and focus group and should take no more than 2 hours of your time. I have asked you to participate because you are in a position to provide informed opinions regarding diabetes care model.

If you are interested in participating, I would be glad if you would contact me, my supervisor Dr. Valerie Gay or the local independent contact person Dr. Ryan Alturki.

You are under no obligation to participate in this research.

Yours sincerely,

Email: fuhid.alanazi@student.uts.edu.au
Phone number: [redacted]
Phone number: [redacted]

Email: Valerie.Gay@uts.edu.au
Phone number: + 61 2 9514 4645

Email: rmturki@uqu.edu.sa
Phone number: [redacted]

NOTE:
This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 2478 Research.Ethics@uts.edu.au), and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

Page 1 of 1

UTS UNIVERSITY OF TECHNOLOGY SYDNEY

INVITATION LETTER (Stage 2)

Design and Process Requirements of E-health Models for Personalised Care Management: Focus on Diabetes in Saudi Arabia

Dear Participant

My name is Fuhid Alanazi and I am a student at the University of Technology, Sydney.

I am conducting research on designing the most suitable an ehealth application model for personalised diabetes care and management and would welcome your assistance. The research will involve with evaluate (test) the prototype model and should take no more than 1 hour and 30 minutes of your time. I have asked you to participate because you are in a position to provide informed opinions regarding the diabetes prototype application mode.

If you are interested in participating, I would be glad if you would contact me, my supervisor Dr. Valerie Gay or the local independent contact person Dr. Ryan Alturki.

You are under no obligation to participate in this research.

Yours sincerely,

Email: fuhid.alanazi@student.uts.edu.au
Phone number: [redacted]
Phone number: [redacted]

Email: Valerie.Gay@uts.edu.au
Phone number: + 61 2 9514 4645

Email: rmturki@uqu.edu.sa
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APPENDIX D

Participant Information Sheet

PARTICIPANT INFORMATION SHEET (Stage 1)

Design and Process Requirements of E-health Models for Personalised Care Management: Focus on Diabetes in Saudi Arabia

UTS HREC APPROVAL NUMBER ETH19-3842

WHO IS DOING THE RESEARCH?

My name is Fuhid Alanazi and I am a student at UTS. My supervisor is Dr. Valerie Gay
Email: Valerie.Gay@uts.edu.au
Phone number: +61 2 9514 4645

WHAT IS THIS RESEARCH ABOUT?

The research aims to identify the design requirements and process engineering requirements for an e-health based personalised diabetes management system and using them for modelling and implementation in a Saudi hospital. The aim of this research is design the most suitable an ehealth app model for personalised diabetes care and management to keep the disease under control and managing person with diabetes at home by remotely accessible for Saudi patients.

WHY HAVE I BEEN ASKED?

You have been asked to participate because this study is designed for person with diabetes who is under home care, their family/friends, healthcare professionals dealing with diabetes, modelling specialists, IT specialist of the hospital and you are in a position to provide informed opinions regarding the ehealth modelling requirements. The hospital will email and texts everyone on the patient list about the research, and then the patients can choose whether to contact me for further information. If so, they can contact me if they would like to be involved in the research. Same producer will be applied to doctors, nurses, IT specialists and family members. No one will be selected that in any way known to the researcher

IF I SAY YES, WHAT WILL IT INVOLVE?

I will invite you for a brief questioner and focus group that will take you approximately 2 hours to complete and it will be audio recorded. It will be conducted to extract ideas on the design requirements of self-management e-health model for Saudi person with diabetes. The idea is to brainstorm into coming up with fresh innovative ideas based on your knowledge and experience. This is done to identify the inputs for modelling the eHealth requirements. This step is will lead to processes and systems requirements for the ehealth model.

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some risks/inconvenience. While no harm is intended, invasion of privacy, embarrassment or distress may result in unforeseen ways. You will be reporting and discussing your experience, which will require some level of personal disclosure. While of both questioner survey and focus group are anonymous, there is a small chance that you may feel privately embarrassed if you not managed to perform a tasks correctly. Please be aware that you won't be judged on your performance we are only seeking your personal opinion and experience on the ehealth modelling requirements.

Please be aware that participation in this research is voluntary and you are free to withdraw from participating in this research at any time without consequences.

DO I HAVE TO SAY YES?

Participation in this study is voluntary. It is completely up to you whether or not you decide to take part.

WHAT WILL HAPPEN IF I SAY NO?

You are free to withdraw from participating in this research at any time without consequences. I will thank you for your time so far and won't contact you about this research again.

IF I SAY YES, CAN I CHANGE MY MIND LATER?

You can change your mind at any time. However, please advise as soon as possible of any intension to withdraw. I will thank you for your time so far and I will not use your data any further and all information will be deleted.

WHAT IF I HAVE CONCERNS OR A COMPLAINT?

If you have concerns about the research that you think I, my supervisor or the local independent contact person Dr Ryan Alturki can help you with, please feel free to contact us on:

Email: fuhid.alanazi@studnet.uts.edu.au
Phone number: [redacted]
Phone number: [redacted]

Email: Valerie.Gay@uts.edu.au
Phone number: + 61 2 9514 4645

Email: rmturki@uqu.edu.sa
Phone number: [redacted]

NOTE:
This study has been approved in line with the University of Technology Sydney Human Research Ethics Committee [UTS HREC] guidelines. If you have any concerns or complaints about any aspect of the conduct of this research, please contact the Ethics Secretariat on ph.: +61 2 9514 2478 or email: Research.Ethics@uts.edu.au], and quote the UTS HREC reference number. Any matter raised will be treated confidentially, investigated and you will be informed of the outcome.

UTS UNIVERSITY OF TECHNOLOGY SYDNEY

CONSENT FORM (Stage 1)

Design and Process Requirements of E-health Models for Personalised Care Management: Focus on Diabetes in Saudi Arabia

UTS HREC APPROVAL NUMBER ETH19-3842

I ____________________ agree to participate in the research project "Design and Process Requirements of E-health Model for Personalised Care Management of Diabetes " UTS HREC approval number ...... being conducted by Fuhid Alanazi [redacted]

I understand that the purpose of this study is to identify the design requirements and process engineering requirements for an e-health based personalised diabetes management system and using them for modelling and implementation in a Saudi hospital. The aim of this research is design the most suitable an ehealth application model for personalised diabetes care and management to keep the disease under control and managing person with diabetes at home by remotely accessible for Saudi patients.

I understand that I have been asked to participate because this study is designed for person with diabetes who is under home care, their family/friends, healthcare professionals dealing with diabetes, modelling specialists, IT specialist of the hospital and I amin a position to provide informed opinions regarding the ehealth modelling requirements.

While no harm is intended, invasion of privacy, embarrassment or distress may result in unforeseen ways. You will be reporting and discussing your experience, which will require some level of personal disclosure. While of both questionary survey and focus are anonymous, there is a small chance that you may feel privately embarrassed if you not managed to perform a tasks correctly. Please be aware that you won't be judged on your performance we are only seeking your personal opinion and experience on the ehealth modelling requirements.

Please be aware that participation in this research is voluntary and you are free to withdraw from participating in this research at any time without consequences. Please do not **discuss focus group comments outside of the focus group** session.

I agree to be:
☐ Audio recorded
☐ Contact for stage 2

I agree to keep confidential all information including all conversations and discussions, materials and methods provided to me by the UTS research team.

I agree that the research data gathered from this project may be published in a form that:
☐ Does not identify me in any way

I am aware that I can contact Fuhid Alanazi or the local independent contact person, Dr Ryan Alturki via his email: rmturki@uqu.edu.sa or phone number: [redacted] if I have any concerns about the research. I also understand that I am free to withdraw my participation from this research project at any time I wish, without consequences, and without giving a reason.

I agree that Fuhid Alanazi has answered all my questions fully and clearly.

____ ____/____/____

Name and Signature [participant] Date

UNIVERSITY OF TECHNOLOGY SYDNEY

____ ____/____/____

Name and Signature [researcher or delegate] Date

*** Witness to the consent process**

If the participant, or if their legally acceptable representative, is not able to read this document, this form must be witnessed by an independent person over the age of 18. In the event that an interpreter is used, the interpreter may not act as a witness to the consent process. By signing the consent form, the witness attests that the information in the consent form and any other written information was accurately explained to, and apparently understood by, the participant (or representative) and that informed consent was freely given by the participant (or representative)

UTS UNIVERSITY OF TECHNOLOGY SYDNEY

PARTICIPANT INFORMATION SHEET (Stage 2)

Design and Process Requirements of E-health Models for Personalised Care Management: Focus on Diabetes in Saudi Arabia

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You have been asked to participate because this study is designed for person with diabetes who is under home care, their family/friends, healthcare professionals dealing with diabetes, modelling specialists, IT specialist of the hospital and you are in a position to provide informed evaluation regarding the designed ehealth prototype.

IF I SAY YES, WHAT WILL IT INVOLVE?

I will invite you to evaluate (test) the prototype model that will take you approximately 1 hour and 30 minutes to complete and it will be audio recorded. It will be conducted to improving the designed prototype model of self-management for e-health for Saudi person with diabetes. The idea is to identifying the strength and weakness to improve the prototype based on your knowledge and experience.

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some risks/inconvenience. While no harm is intended, invasion of privacy, embarrassment or distress may result in unforeseen ways. You will be reporting and discussing your experience, which will require some level of personal disclosure. While evaluation (test) is anonymous, there is a small chance that you may feel privately embarrassed if you not managed to perform a tasks correctly. Please be aware that you won't be judged on your performance we are only seeking your personal opinion and experience on the ehealth prototype.

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UTS UNIVERSITY OF TECHNOLOGY SYDNEY

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☐ Does not identify me in any way

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I agree that Fuhid Alanazi has answered all my questions fully and clearly.

____ ____/____/____

Name and Signature [participant] Date

____ ____/____/____

Name and Signature [researcher or delegate] Date

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