A Conceptual Model using Ambient Assisted Living to Provide a Home Proactive Monitoring System for Elderly People in the Kingdom of Saudi Arabia

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Abstract

The growth in the ageing population is rapidly increasing and their care cost will be a challenging issue in the future. The number of elderly people worldwide (defined as those aged 60 years and older) was 202 million in 1950; this number has since quadrupled to reach 901 million and is expected to triple again by 2100. In particular, the number of elderly people in the Kingdom of Saudi Arabia (KSA) is increasing rapidly, from 5% of the total population in 2015 to a forecasted 20.9% by 2050. Clearly, the cost of taking care of elderly people is already a challenge, but it will be very difficult to meet in the future, when it will lead to a much higher expenditure on healthcare facilities. Furthermore, although elderly people are vulnerable to a decline in their health, they do not wish to live as they did in the 1970s to 1990s. Instead, their desire is to live independently in their own homes and continue to practice normal activities. In fact, Saudi culture is changing, and the children tend not to live with their parents as they used to. However, the literature review indicates that there is a lack of professionally designed systems that can fulfil the growing needs or requirements of elderly people in the KSA.

These demographic changes raise a number of challenges related to the elderly people's quality of life, including health, autonomy, care, social communication, and the utilisation of institutional services. These challenges require novel approaches to provide dependable self-adapting technological innovations. The era of Information and Communication Technology (ICT) has changed the world of the ageing population. Ambient Assisted Living (AAL) aims to improve the quality of life of elderly people, and to provide them with technologies and services that support their daily activities, help them to live longer and remain independently at home.

The aims and objectives of this research are to review Ambient Assisted Living Technology, to provide examples of relevant technologies and applications, and to examine attitudes and perceptions of elderly people towards using AAL technologies in the KSA. This research also explores the factors of AAL, identifying those that affect the adoption of these technologies in the KSA, by conducting a systematic review, and using quantitative and qualitative analyses.

The questionnaire results showed that elderly Saudi Arabians are willing and intending to accept and use AAL technologies, and that there are many factors that influence their adoption and use of AAL technologies. This provides an insight for solutions to the provision of support for their independent living.

Thus, we developed a conceptual model using AAL to provide a Home Proactive Monitoring System (AALHPMS) that supports the stakeholders in adopting AAL technologies. We envisage that the AALHPMS can fulfil the needs and requirements of elderly people, motivate healthcare providers to implement AAL technologies, and assist the Saudi Government to make suitable provision for issues associated with the ageing population. In addition, a knowledge-based-system was built using a rule-based system. Experiments using Smart watches were conducted to monitor the heart rates. Further experiments using ZigBee, Bluetooth beacons, and surveillance cameras technology were also undertaken for monitoring the movement of elderly persons at their home. A website was also developed to disseminate knowledge related to ageing population and AAL technology in Saudi Arabia.

Keywords: Ambient Assisted living, Elderly People, Kingdom of Saudi Arabia, Conceptual Model, Proactive Monitoring System

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Majid Hamdan Alsulami

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Dedication

This thesis is dedicated to:

My father, ***Hamdan***

My mother, ***Obidah***

My wife, Azzah

My brothers and sisters

My children: Meshal, Ghaday, Huda, Hamdan and Tameem

List of Publications

This thesis consists of an overview of the following publications:

Journal publications: 2

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[J.2] An extended paper, Alsulami, M.H. & Atkins, A.S. (2016). A Model of a Proactive Ambient Assisted Living System to Monitor Elderly People in The Kingdom of Saudi Arabia. *International Journal of Research in Engineering and Technology (IJRET) Vol. 4, No. 1, 2016 SSN 2277 – 4378.*

Book Chapter: 1

[CB.1] Alsulami M.H., Atkins A.S., Campion R.J. (2018) Factors Influencing the Adoption of Ambient Assisted Living Technologies by Healthcare Providers in the Kingdom of Saudi Arabia. *In: Ezziyyani M., Bahaj M., Khoukhi F. (eds) Advanced Information Technology, Services and Systems Book. AIT2S 2017. Lecture Notes in Networks and Systems, vol 25. Springer, Cham*. DOI: 10.1007/978-3-319-69137-4_1.

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[C.1] Alsulami, M.H. & Atkins, A.S. (2016). Elderly Saudi Arabians' Perceptions and Attitudes towards using Ambient Assisted Living Technologies. *Proceedings of 64th The IIER International Conference, Barcelona, Spain, 4th March 2016, ISBN: 978-93-85973-53-6.*

[C.2] Alsulami, M.H. & Atkins, A.S. (2016). A Conceptual Framework Using Ambient Assisted Living to Provide a Proactive Monitoring System for Elderly Saudi Arabians at Home, *2016 London International Conference on Recent Trends in Engineering and Technology, 26th May 2016.*

[C.3] M. H. Alsulami, A. S. Atkins and R. J. Campion, the use of smart watches to monitor heart rates in elderly people: A complementary approach, *2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA)*, Agadir, 2016, pp. 1-6. DOI: 10.1109/AICCSA.2016.7945809.

[C.4] Alsulami, M.H. & Atkins, A.S, Campion, R. (2017). Challenges and Barriers Facing Healthcare Providers in the Kingdom of Saudi Arabia to Adopt Ambient Assisted Living Technologies: Community of Practice Study. *Advanced Information Technology, Services and Systems (AIT2S-17), April 2017, IEEE, At Morocco, Tangier*.

[C.5] M. H. Alsulami, A. S. Atkins and R. J. Campion, A. Alaboudi, An Enhanced Conceptual Model for Using Ambient Assisted Living to Provide a Home Proactive Monitoring System for Elderly Saudi Arabians, *2017 IEEE/ACS 14th International Conference of Computer Systems and Applications (AICCSA)*, Nov 2017, Hammamet, 2017.

Awards

1) The **Best paper** in the 64th IIER International Conference, Barcelona, Spain, 4th March 2016. Entitled 'Elderly Saudi Arabians' Perceptions and Attitudes towards using Ambient Assisted Living Technologies'.

2) The **Best session paper** in the International Conference on Recent Trends in Engineering and Technology, 26th May 2016, London, United Kingdom. Entitled 'A Conceptual Framework Using Ambient Assisted Living to Provide a Proactive Monitoring System for Elderly Saudi Arabians at Home'.

3) The **Best paper** that makes the most significant contribution in Advanced Information Technology, Services and Systems (AIT2S-17), April 2017, IEEE, Morocco, Tangier. Entitled 'Challenges and Barriers Facing Healthcare Providers in the Kingdom of Saudi Arabia to Adopt Ambient Assisted Living Technologies: Community of Practice Study'.

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List of Abbreviations

AAL	Ambient Assisted Living
AALHPMS	Ambient Assisted Living to Provide a Home Proactive Monitoring System
AR	Assistive Robotic
B	Business
BIS	Business Innovation and Skills
BLE	Bluetooth Low Energy
bn	Billion
BPM	Beats per Minute
CAD	Canadian Dollar
CC	Cloud Computing
CEO	Chief Executive Officer
CITC	Communications and Information Technology Commission
CoP	Community of Practice
CS	Communication Structure
CVD	Cardiovascular Disease
DAP	Data Acquisition and Processing
DI	Data Integration
DOI	Diffusion of innovations
DSS	Decision Support System
e-T	e-Textile
ECG	Electrocardiogram
GOSI	General Organisation for Social Insurance
H	Human
HF	Heart Failure
HIS	Health Information Systems
HOT-fit	Human, Organization and Technology-fit factors
HR	Heart Rate
ICT	Information and Communication Technologies
IoT	Internet of Things
IS	Information System
IS Triangle	Information System Strategy Triangle
IT	Information Technology
KBS	Knowledge-Based System
KR	Knowledge Reasoning
KSA	Kingdom of Saudi Arabia
LEDs	Light-Emitting Diodes

m	Million
MENA	Middle East and North of Africa
MOH	Ministry of Health
MWS	Mobile and Wearable Sensors
O	Organisation
OSA	Obstructive Sleep Apnea
PCC	Proactive Control Centre
PHC	Primary Health Care
PMS	Proactive Monitoring System
PPA	Public Pension Agency
PPG	Photoplethysmogram
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QOF	Quality of Life
RFID	Radio-Frequency Identification
SDL	Saudi Digital Library
SH	Smart Homes
SR	Saudi Riyal
SUL	Staffordshire University Library
T	Technology
TAM	Technology Acceptance Model
TOE	Technology-Organization- Environment framework
UK	United Kingdom
US	United State
USA	United States of America
UTAUT	Unified Theory of Acceptance and Use of Technology
UWB	Ultra-Wide Band
V	Visualisation
WHO	World Health Organisation
Wi-Fi	Wireless Fidelity
WSN	Wireless Sensor Networks

Chapter 1: Introduction

1.1: Background and Motivation

The basis for defining elderly people varies, and the definition can be categorised into three categories: 1) change in social role, 2) chronology, and 3) change in capabilities. In practice, the chronological age is the most common system, as outlined by the World Health Organisation (WHO). The United Nations defines elderly people as people of 60 years and above (United Nation, 2013). Further, in many countries with high incomes they refer to elderly people as those aged over 65 and, consequently, this is the age for qualification for social security benefits (Butsch et al., 2013). However, this research will refer to elderly people as those who are 60+, according to the retirement policy in the KSA (Alsufiani et al., 2015).

The world population in 2015 was 7.34 billion (bn). This number is projected to reach 8.5bn in 2030 and 9.7bn in 2050. By 2100, the population would be 11.2bn. People aged 60 years and over (901 million) in 2015 comprised 12% of the world population. Further, the number of elderly people in the world is expected to be 1.4bn by 2030 and 2.1bn by 2050, and might increase to 3.2bn by 2100. The growth in the ageing population is rapidly increasing, and their care cost will be a challenging issue in the future (United Nations, 2015). The population of the KSA in 2015 was 31.5m and is estimated to be 39.1m in 2030. This number will increase to 46.1m in 2050 and reach 47.6m in 2100. While the Saudi Arabian population continues to increase, the ageing population will also continue to increase rapidly (United Nations, 2015).

The current status of elderly people in the KSA is manageable, because the proportion is only 5%. However, the ageing population in the KSA will be unmanageable in the future, since the percentage will increase sharply to reach 20.9% in 2050, and will further rise to 33.5% by 2100 (Abusaaq, 2015; United Nations, 2015d; Al-shehri, 2012).

A study conducted in 2013 in the KSA, with 10,735 participants over 60 years of age, showed that 45.8% take medication (Moradi-Lakeh et al., 2015). A survey of 2,095 participants demonstrated the high percentage of risk of Obstructive Sleep Apnea (OSA) among the elderly (≥60 years), which was 41% (Alruwaili et al., 2015). Worldwide, falls are also another major concern amongst elderly people (Al

Saif et al., 2012).

Heart failure (HF) and cardiovascular diseases are considered major concerns that affect elderly people in the KSA (AbuRuz et al., 2015; Albugami et al., 2015). '*Cardiac failure is an inability of the heart to deliver blood (and therefore oxygen) at a rate commensurate with the requirements of the metabolising tissues at rest or during light exercise*' (McMurray, 1996).

Many elderly people face decline in their health when they become older, and need some form of support in their daily activities, as well as facilities to monitor their health (Hossain et al., 2014; Al Saif et al., 2012; Blasco et al., 2014).

The increase in the ageing population worldwide compared to the increase in the world population presents challenges for both healthcare providers and elderly people (Al Saif et al., 2012). In particular in the KSA, the growing number of people included in the ageing population presents many challenges to the Saudi Arabian Government: 1) the increment of persons requesting pension benefits will increase; 2) the economy will decrease; 3) healthcare expenditures will increase, and 4) spending will be more and saving will be less (Abusaaq, 2015).

These challenges and issues require novel approaches for dependable self-adapting technological innovations. AAL is advocated as a potential form of technology that can involve in assisting and helping elderly people to overcome their challenges, and to fulfil and meet their needs and requirements as their lives and circumstances change with age. The continuous growth in the number of elderly Saudi Arabians requires the development of a decision-making holistic framework for using AAL to support the stakeholders, and a model using AAL in order to improve the quality of life, to live independently and longer, to improve their health, and to remain active.

1.2: Research Questions

This research attempts to answer the following research questions, which are derived from the research motivation:

Q1: What are the factors affecting the adoption of AAL technologies in the KSA?

Q2: How can a conceptual model be developed that can assist the stakeholders to adopt and implement the AAL technologies in the KSA?

1.3: The Research Aim and Objectives

The aim of this research is to develop a conceptual model using Ambient Assisted Living to provide a Home Proactive Monitoring System for elderly people in the KSA (AALHPMS), one that supports its stakeholders (elderly people, healthcare providers and decision makers) in adopting Ambient Assisted Living (AAL) technologies in the Kingdom of Saudi Arabia (KSA), and that is integrated with an individual rule base system to provide a proactive monitoring system.

This research is developed to achieve the following objectives, which are derived from the research questions:

i. To carry out a literature review on:
   a. The aging population worldwide and in the KSA
   b. The existing Ambient Assisted Living Technologies
   c. The critical factors that affect the adoption and deployment of Ambient Assisted Living Technologies in the KSA.

ii. To conduct a survey in the Kingdom of Saudi Arabia:
   a. To extract the Saudi elderly people's attitudes and perceptions towards using Ambient Assisted Living Technology
   b. To identity the factors that affect adoption of AAL technologies.

iii. To conduct a Community of Practice (CoP) with:
   a. Healthcare providers in the Kingdom of Saudi Arabia, in order to extract the factors that affect the adoption and implementation of AAL technology
   b. UK Age in Stafford, to review the system they use for elderly people.

iv. To conduct experiments using Smart watches, ZigBee technology, Bluetooth beacons and surveillance cameras.

v. To develop a conceptual model that supports the adoption of Ambient Assisted Living Technology in the KSA, with a specific focus on the elderly population, to provide a proactive monitor system. This development includes:
   a. Conducting a literature review on the existing works related to monitoring systems
   b. Designing a knowledge-based system (KBS) with rule-based reasoning, which will be an important feature for the developed model

c. Designing the layout of the Proactive Control Centre (PCC), which can predict what type of issues and problems could happen to the elderly person, and that supports the appropriate action tailored to the specific problems.

vi. To design a web website, AgeinginKSA, for sharing and disseminating knowledge among individuals in the KSA

vii. To conduct a focus group in order to evaluate the conceptual model, SECI model tools, and the usability of the AgeinginKSA website.

1.4: Research Design

This research was developed in order to answer the research questions and achieve the aforementioned objectives by the following steps:

- A literature review was conducted about the ageing population worldwide and in the KSA, the AAL technologies, and the factors that affect the adoption and implementation of AAL technologies
- A literature review was conducted about the existing works that related to the developed model. This guided us to have an overview about the layers and concepts that have been used in order to fill the gaps of knowledge
- A literature review was carried out about the SECI model, and the web tools that can be used to share knowledge in order to apply the four SECI modes
- A literature review was conducted about the websites' design and their evaluations instruments. This helped us to identify the standards and criteria that are mostly used to design a professional website
- A primary research using a questionnaire was carried out in order to extract the attitudes and perceptions of elderly people towards using AAL technologies and to identify the factors that affect the adoption of AAL technologies
- A Community of Practice (CoP) was conducted with the healthcare providers in the KSA in order to identify the factors that affect the adoption and implementation of AAL technologies in the KSA
- A Community of Practice (CoP) was conducted with Age UK to gain knowledge about their system. The goal of this was to share information and experiences with practitioners. This helped researchers to transfer the knowledge from Age UK to the stakeholders in the KSA, and was accomplished by holding meetings and

documenting the mission, objectives, processes, etc.

- A decision making holistic framework for using AAL was developed to support the stakeholders based on a literature review, elderly people questionnaire, and CoP with healthcare provider.
- Experiments were conducted using Smart watches, ZigBee technology, Bluetooth beacons, and surveillance cameras
- A conceptual model using Ambient Assisted Living was developed to provide a Home Proactive Monitoring System for elderly people in the KSA (AALHPMS). The developed model can support the stakeholders (decision-makers, elderly people and healthcare providers) in adopting AAL technologies as a technological innovation for providing elderly people with better quality of life and the ability to live independently
- A knowledge-based system (KBS) was developed to operate, for transferring knowledge to resolve any arising issues and problems. A KBS can be used with rule-based reasoning, which is developed as an important feature for the proposed framework. The KBS will act as a decision support system (DSS), which will take an appropriate decision and action when abnormal issues occur. (It should be RBS)
- A design was produced of the layout of a Proactive Control Centre (PCC), which includes a proactive monitoring system that can predict what type of issues and problems could happen to the elderly person, and that supports the appropriate action tailored to the specific problems. This PCC consists of a set of Smart devices handled by skilled and professional staff, and includes the KBS and a dashboard for each elderly person who is subscribed in the system
- A website was designed and named ageinginksa.org. It is used to share and disseminate knowledge, and to create awareness amongst the community concerning the ageing population and ALL technologies used to provide elderly people with the quality of life and services needed
- A focus group evaluation with nine participants was carried out in the KSA in order to evaluate the conceptual model, the SECI web tools, and the usability of AgeinginKSA website.

1.5: Research Contributions

The main contribution of this research is to develop a conceptual model using

Ambient Assisted Living to provide a Home Proactive Monitoring System for elderly people in the KSA (AALHPMS). This will support elderly people, healthcare providers and decision-makers in adopting Ambient Assisted Living (AAL) in the Kingdom of Saudi Arabia (KSA). To the best of our knowledge, there are no studies that have investigated the use of AAL technologies in the KSA to address the ageing population's challenges and issues with the purpose of providing elderly people with a better quality of life and the ability to live independently. Besides this main contribution, this research also makes the following contributions:

i. The development of a decision-making holistic framework for using AAL technologies to support elderly people, healthcare providers and decision-makers, in order to decide whether to adopt AAL technologies or not

ii. Conducting experiments using Smart watches, ZigBee technology, Bluetooth beacons and surveillance cameras in order to ensure that the technologies are reliable and significant to be adopted

iii. Designing the layout of a Proactive Control Centre (PCC) and its operational processes. A PCC consists of a multiscreen with the Proactive Monitoring System (PMS). The PMS can be used to predict what type of issues and problems could happen to the elderly person monitored, based on knowledge reasoning, thereby supporting appropriate actions that are tailored to the specific problems. The operational processes describe the processes that should be followed by elderly people to register in the proactive monitoring system

iv. Designing a website, in order to make the community aware about AAL technologies and the ageing population in the KSA. This website aims at using and implementing the SECI web tools that allow participants and practitioners to share their knowledge about AAL technologies, which are considered as a new concept in the KSA. Furthermore, this website allows elderly people to overcome the isolation barriers that affect their social life, by participating and communicating with others through using the SECI web tools. Families and relatives can benefit from the website by using documents and videos, which will provide them with instructions, guidelines, policies and technologies that help them deliver better quality of life to elderly people.

1.6: Research Methodology

A methodology can be defined as '*the theory of how research should be undertaken, including the theoretical and philosophical assumptions upon which research is based and the implications of these for the method or methods adopted*' (Saunders et al., 2009). Saunders et al. (2009) developed the concept of the research onion, in order to define the steps that researchers can follow to form a successful process. Firstly, the researcher should describe what the research philosophy requires. Secondly, this leads to the appropriate research approach. Thirdly, the research strategy is adopted to carry out the study and then, the time horizon is specified in the fourth step. Finally, a methodology is considered to collect the data. These layers are illustrated in Figure 1.1.

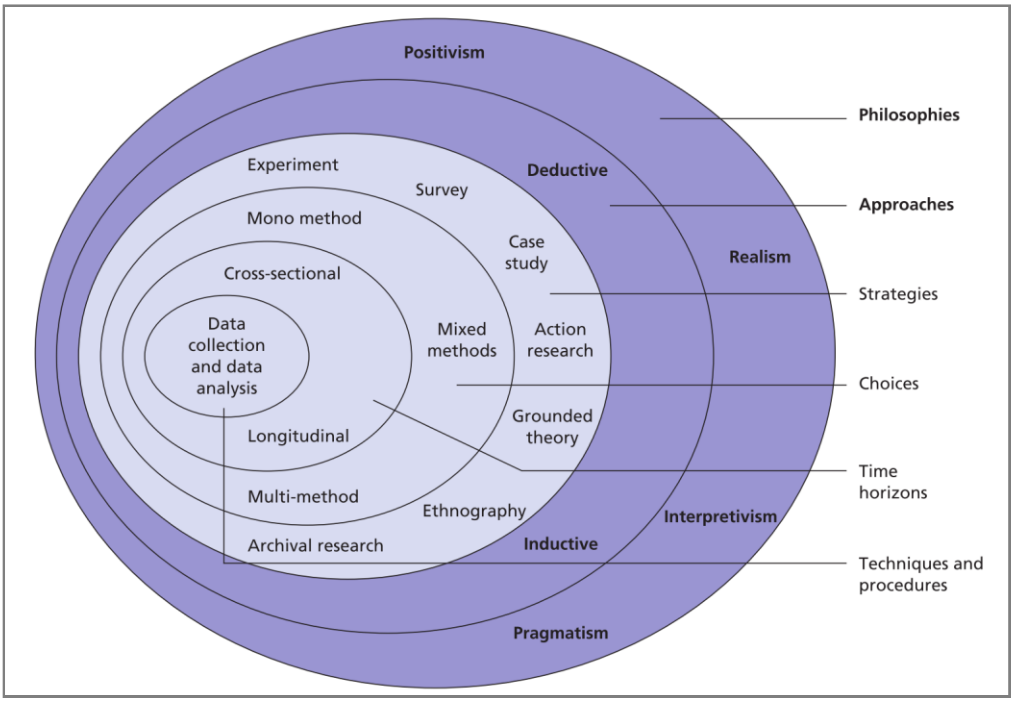


Figure 1.1: Onion Research
Source: (Saunders et al., 2009)

1.6.1: Research Philosophy

The research philosophy discusses a set of beliefs regarding the nature of reality that will be studied. There are numerous philosophies, including positivism, realism, interpretivism and pragmatism (Saunders et al., 2009).

- Positivism proposes that reality exists independently and can not be affected by the researcher. It can be witnessed and explained from an objective perspective and related to natural science (Saunders et al., 2009). Thus, reality can be discovered by using quantitative methodology (Tuli, 2011)
- Realism assumes that the reality is totally independent of the mind. It adopts a scientific approach that assists in developing knowledge. This presumption supports the collection and the understanding of data (Saunders et al., 2009)
- Interpretivism is to understand distinctions amongst humans in their roles as social actors. This philosophy assumes that there are several clarifications of reality, and it maintains that these clarifications are a portion of the scientific knowledge that researchers study (Saunders et al., 2009). The interpretive researchers believe that reality is made by humans. Therefore, they use qualitative methodology in order to investigate, interpret, and explain reality (Tuli, 2011)
- Pragmatism is a combination of one or more philosophies for a practical research study. It holds that the research question is the essential aspect of the research philosophy adopted, and the answer to a specific question can be accepted by one approach rather than another (Saunders et al., 2009).

The purpose of this research is to solve the ageing population problem in the KSA and fill this gap by using AAL technologies. The development of the holistic framework and the conceptual model involves in investigating existing works and by different stakeholders, which results in different views. Using pragmatism philosophy allows the researcher to use mixed methods, which provide the researcher with the abilities to investigate the ageing population phenomena in the KSA and identify the factors affecting the adoption of AAL technologies. According to the aforementioned justification of methodology, this research adopts the pragmatism philosophy.

1.6.2: Research Approaches

There are two types of approaches to research: deductive and the inductive:

- The deductive approach develops a theory based on previous findings (literature), experience, observations, etc., and then derives a hypothesis from the theory and makes observations. Then, the hypothesis may be confirmed or rejected (Saunders et al., 2009)
- The inductive approach starts with observations, and finds patterns to generate a hypothesis. Then, it validates and tests the hypothesis that forms a theory (Saunders et al., 2009).

This research adopts the deductive approach, which involves using literature review in order to investigate the ageing population challenges, to identify the factors that affect the adoption of AAL technologies in order to develop a holistic decision framework to be the foundation for the developed conceptual model by investigating the existing work that have been developed to monitor people’s health.

1.6.3: Research Strategy

The research strategy aims at assisting researchers to carry out their work (Saunders et al., 2007). Research strategies can be classified into three types: quantitative, qualitative and mixed approaches (Creswell, 2003).

1.6.3.1: Quantitative Strategies

Quantitative research examines hypotheses by defining the relationships between variables and measuring the incidence of observations. Quantitative research creates numerical data and is correlated with positivism and beliefs that reality is measured and observed objectively. Moreover, it is defined as ‘deductive’ and tends to examine a priori hypothesis (Tariq & Woodman, 2010).

There are two major quantitative strategies:

Surveys assist the researcher to collect data by different methods such as using online questionnaire, telephone interviews, email or mail questionnaires, etc. This data can be analysed quantitatively using descriptive and statistical techniques (Saunders et al., 2009; Gable, 1994).

Experimental research means the strategy of making the process of research, which examines the results of an experiment against the expected results (Saunders et al., 2009).

1.6.3.2: Qualitative Strategies

Qualitative research discovers new subjects or issues through making sense of implications for the persons involved in a study (Hoe.J & Hoare.Z, 2013). It creates non-numerical data, using methods such as interviews, observation, semi-structured interviews and focus group negotiations. Qualitative research is an interpretive perspective, which indicates that the beliefs come in several realities formed by individual opinions, context and meaning. Furthermore, it is inductive, which frequently includes open-ended questions where hypotheses are generated from data (Tariq & Woodman, 2010). There are five major qualitative strategies: grounded theory, case study research, action research, ethnography, and archival research.

1.6.3.3: Mixed Methods

Mixed methods strategies concentrate on gathering, investigating, and using a combination in one study, of both quantitative and qualitative data, numeric and text, in one study to understand and solve the problem, or to answer the research question (Tariq & Woodman, 2010; Creswell, 2003).

Based on the aim of this research, a mixed method approach was used to analyse and evaluate the predictive outcomes and results. This research involves the use of both primary and secondary data, and it has used:

- A survey strategy, in order to extract attitudes and perceptions of elderly people regarding the level of acceptance of the use of AAL technologies in the KSA, and to identify the factors that affect the adoption of AAL technologies in the KSA. The total numbers of respondents to the survey was 420, and 194 of these responses were fully completed. This sample size is almost double the accepted level that is recommended by Kline (1979) and Gorsuch (1983) (MacCallum et al., 1999). In addition, Burgess (2001) indicated that it is common that a completed questionnaire response rate can be 20% of the entire responses. More detail is given in Section 5.2.6

- A Community of Practice (CoP) with healthcare providers, in order to identify the factors that affect the implementation of AAL technologies in the KSA. Four CEOs and an Executive Vice President of healthcare providers were involved. More detail is given in Section 5.5

- Many experiments using Smart watches, chest strap, tracking systems and surveillance cameras were conducted in order to ensure that the technologies are reliable and significant to be adopted. More detail is given in Chapter 6

- A focus group study was conducted to evaluate the conceptual model, the SECI web tools, and the usability of the website. The acceptable size for a focus group can be between six and ten participants (Bartels et al., 2003). Nine participants (three IT specialists, three healthcare providers and three elderly people) attended. More detail is given in Chapter 9.

The research methodology that is used in this research is illustrated in Figure 1.2.

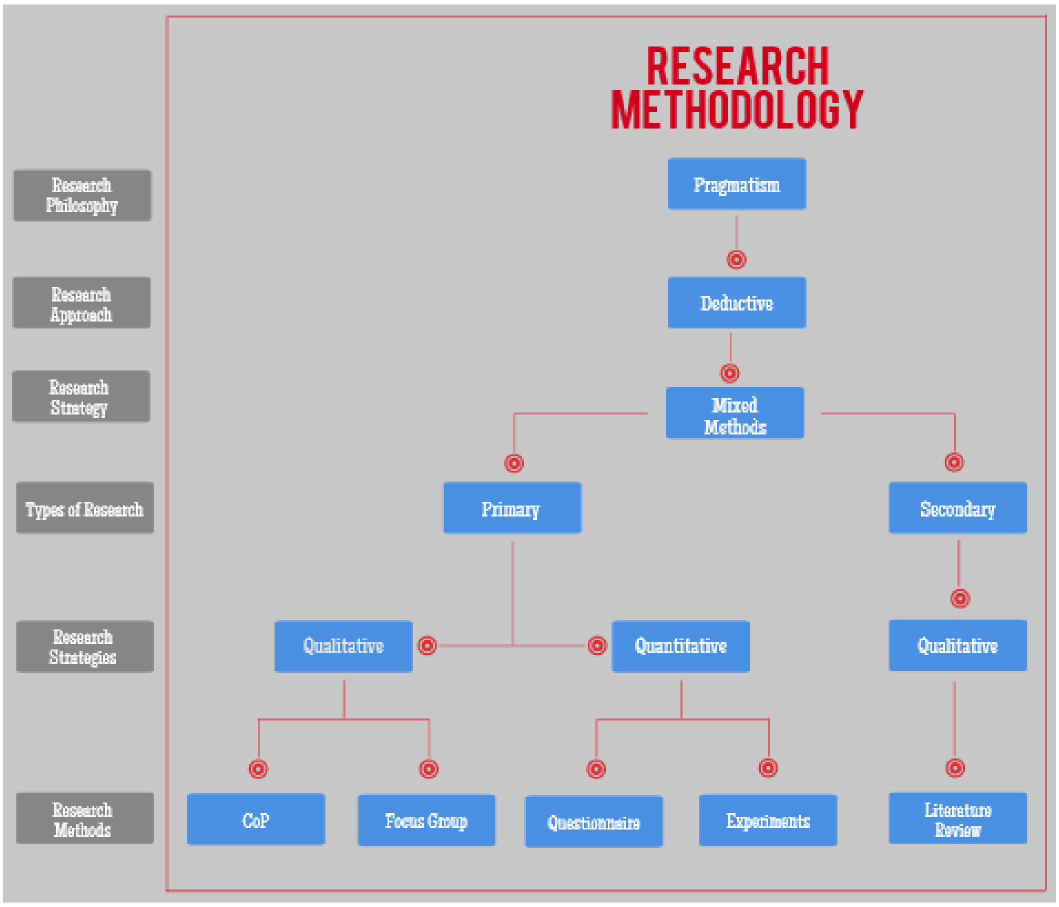


Figure 1.2: The Research Methodology Processes

1.7: Ethical Statement

The researcher obtained an approval for the Fast-Track Ethical Form (Appendix 1) by the University Ethical Committee, before publishing the questionnaire. The questionnaire was delivered to elderly Saudi people of age 60 years or more. The participants were informed about their consent by the following statements:

- DO NOT participate in this questionnaire if you are vulnerable to constraint or inappropriate influences (e.g., unable to agree, under 18 years, prisoner, etc.)
- The main procedures will be described to participants in advance, so that they are informed about what to expect
- Cooperating by answering every question will help us to understand important factors regarding AAL acceptance; however, you are not required to respond to every question
- Your participation in this questionnaire is voluntary
- The participants have the right to withdraw from the research at any time and for any reason
- There are no direct benefits to you for participating in this research
- There are no risks associated with participation. By your return of the completed questionnaire, you agree to participate in this study
- The participants must be willing to be debriefed, e.g., to find out more about the study and its results.

1.8: Structure of the Thesis

This thesis is composed of ten chapters, as illustrated in Figure 1.3.

The thesis structure is as follows:

Chapter 1 discusses the motivation for developing this thesis, the context of this investigation, its aim and objectives, its contribution to knowledge, the research philosophy, and the structure of this thesis.

Chapter 2 discusses the ageing population worldwide and in the KSA, and outlines the problems arising from its growth. This chapter explains the causes of ageing population and the impact of ageing population on the economy, healthcare provisions, family responsibility and consumer spending.

Chapter 3 describes the definition of ALL and its technologies. Four technologies were reviewed, which are Smart homes, assistive robotics, wearable and mobile devices, and e-Textile. Additionally, IoT and Smart Cities were also discussed and reviewed. The challenges of IoT and Smart cities were clarified.

Chapter 4 discusses the first phase of the development of a decision-making holistic framework for using AAL to support the stakeholders.

Chapter 5 introduces the methodology that is used to extract the attitudes and perceptions of elderly people regarding the level of acceptance for the use of AAL technologies and to identify the factors that affect the adoption of AAL technologies in the KSA. In addition, it discusses the CoP with healthcare providers, conducted in order to identify the factors that affect their adoption and implementation of AAL technologies. This chapter presents also the refinement of the decision-making holistic framework for using AAL to support elderly people.

Chapter 6 presents the definition of heart rate (HR), and the types of technologies that might be used to monitor elderly people at home. This Chapter explains and analyses the experiments that were undertaken using Smart watches, chest strap, Bluetooth beacons, ZigBee and surveillance cameras.

Chapter 7 investigates some of the existing related studies and presents the two phases for developing the conceptual model. It also describes the processes of the conceptual model and each of its layers.

Chapter 8 discusses the knowledge sharing, knowledge management concept, the SECI web tools that can be used to share knowledge and the development of the AgeinginKSA website.

Chapter 9 explains the development processes of evaluation instruments and the results and discussion of evaluations. Three instruments were developed to evaluate the conceptual model, the SECI web tools and the AgeinginKSA website.

Chapter 10 illustrates the motivation for developing this thesis and summarises the contributions and research onion. It also identifies some of the limitation of this research and outlines future work.

The thesis structure is presented in Figure 1.3.

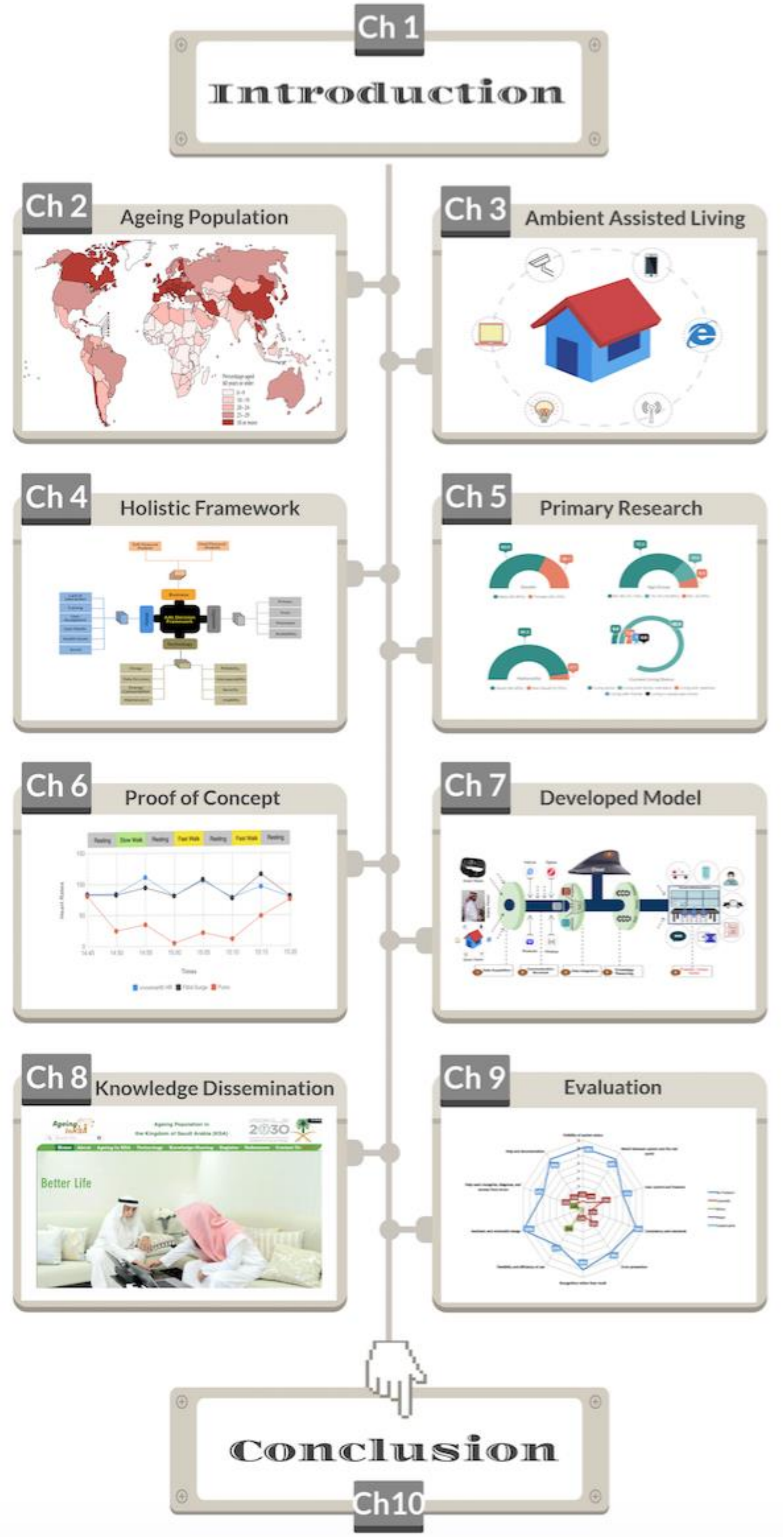


Figure 1.3: The Thesis Structure

1.9: Conclusion

This chapter introduces the context of this investigation, outlining the growth of the ageing population worldwide and in the KSA. The number of elderly people in the world is projected to reach 1.4bn by 2030 and 2.1bn by 2050 and might increase to 3.2bn in 2100. The current situation of elderly people in the KSA is manageable, because their proportion is only 5%. However, the ageing population in the KSA will be a challenging problem in the future, since the percentage will increase sharply reaching 20.9% in 2050, and it may further rise to 33.5% by 2100. This context makes vitally important the introduction of supporting technologies, and the acceptance of their adoption by the aging people, in order to provide them with a better quality of life and the possibility to live independently at their preferred environment.

The definition, development and acceptance strategy for such a technology is the central aim and purpose of this thesis. This chapter presents the aim and objectives, the contribution to knowledge, the research philosophy and the structure of this thesis.

The next chapter will discuss the ageing population in depth, including the worldwide and the KSA statistics, and the impact and causes of the ageing population growth.

Chapter 2: Ageing Population

2.1: Introduction

Chapter 1 presents the context of this investigation, and the aim and objectives, the contribution to knowledge, the research philosophy, and the structure of this thesis.

The main aim of this chapter is to review the populations of the Kingdom of Saudi Arabia (KSA) and the world in 2015 and the projections for the future, showing how the ageing population will keep growing dramatically. It is projected that the world population will be 8,501 million by 2030 (United Nations, 2015d), and that the ageing population will be 16.5%, e.g., 1,402.4 million (United Nations, 2015c).

This chapter focuses on the ageing population of the KSA. It is projected that, in 2100, the KSA population will reach 47.6 million (United Nations, 2015d), and the ageing population will be 33.5% (United Nations, 2015c). This chapter considers the relevant significant research and studies, which have distinguished three particular factors of population demography. These are: fertility, mortality and international migration (United Nations, 2015b; He et al., 2016; Government Office for Science, 2016).

It will then consider the consequent transitional changes that have a significant impact on the economy, healthcare provision, family responsibility and consumer spending, and which will increase the pressure on the governments to pay more attention to this phenomenon and to assess suitable solutions that can meet the requirements of elderly people (United Nations, 2015b; World Health Organization, 2015; Government Office for Science, 2016; He et al., 2016; Bauer et al., 2015; ATKearney & Consumer Goods Forum, 2013; Financial Conduct Authority, 2016).

2.2: World Population Statistics

The world population in 2015 was 7.34 billion (bn). This number is projected to reach 8.5 bn in 2030 and 9.7 bn in 2050. By 2100, the projected population will be 11.2 bn. In 2015, Asia has the highest percentage (60%) with 4.4 bn; Africa accounts for 16% with 1.2bn; 16% of the world population lives in Europe, with 738 million (m); Latin America and the Caribbean have 9%, with 634 m, and 5% are in Northern America (with 358 m) and Oceania (with 39 m) (United Nations, 2015d).

The population of the KSA in 2015 was 31.5 m, and is estimated to become 39.1 m by 2030. This population is projected to increase to 46.1 m in 2050 and reach 47.6 m in 2100 (United Nations, 2015d).

Table 2.1 shows the world and the KSA population.

Table 2.1: Projection of the World Population

Major Area	Population (millions)			
	2015	2030	2050	2100
World	7349	8501	9725	11213
Africa	1186	1679	2478	4387
Asia	4393	4923	5267	4889
Europe	738	734	707	646
Latin America and the Caribbean	634	721	784	721
Northern America	358	396	433	500
Oceania	39	47	57	71
Saudi Arabia	31.5	39.1	46.1	47.6

Source: World Population Prospects: The 2015 Revision. New York, United Nations

2.3: World Ageing Population

The ageing of the population is defined as '*more people living for longer compared with low birth of children*' (The Chartered Institute of Building, 2007). The basis for defining elderly people varies, and the definitions can be categorised into three categories: 1) chronology, 2) change in social role, and 3) change in capabilities. The chronological age is the most common system in practice, as outlined by the World Health Organization (WHO) (WHO, 1875), and is the definition adopted in this chapter.

The United Nations defines elderly people as '*people 60 years old and above*' (United Nations, 2013a). However, in many countries with high incomes, elderly people are those whose age is over 65, and consequently this is their age of qualification for social security benefits (Butsch et al., 2013). In this research we will refer to elderly people as those who are 60+, according to the retirement policy in the KSA (Alsufiani et al., 2015).

Most of the countries across the world are facing growth in the number of ageing population. The ageing population started increasing significantly in developed countries, and then, in the twenty-first century, this became a phenomenon in developing countries as well (United Nations, 2015c).

Globally, people aged 60 years and over comprised 12% of the world population in

2015, with 901 million people. The number of elderly people in the world is projected to reach 1.4bn by 2030 and 2.1bn by 2050, and it might increase to 3.2 billion in 2100 (United Nations, 2015c).

The growth in the number of elderly people is a major factor in making them a high percentage of the world population, and this has been seen in most countries. This proliferation is expected to be particularly significant in less developed regions. Latin America and the Caribbean, for instance, are estimated to experience a more than 70% increase in the proportion of elderly people throughout the next 15 years (from 70.9% to 121%). In Africa and Asia, the percentage of the ageing population is projected to increase greatly, by more than 60% between 2015 and 2030, while in Europe it will increase by 23% (United Nations, 2015c). Table 2.2 shows the number of ageing population globally. The proportion of people aged 60 years or older, by country, in 2015 and in 2050, is illustrated in Figure 2.1 and Figure 2.2.

Table 2.2: Projection of the World Ageing Population

Major Area	Ageing Population (millions)	
	2015	2030
World	900.9	1402.4
Africa	64.4	105.4
Asia	508	844.5
Europe	176.5	217.2
Latin America and the Caribbean	70.9	121
Northern America	74.6	104.8
Oceania	6.5	9.6

Source: Population Ageing: The 2015 Highlight. New York: United Nations

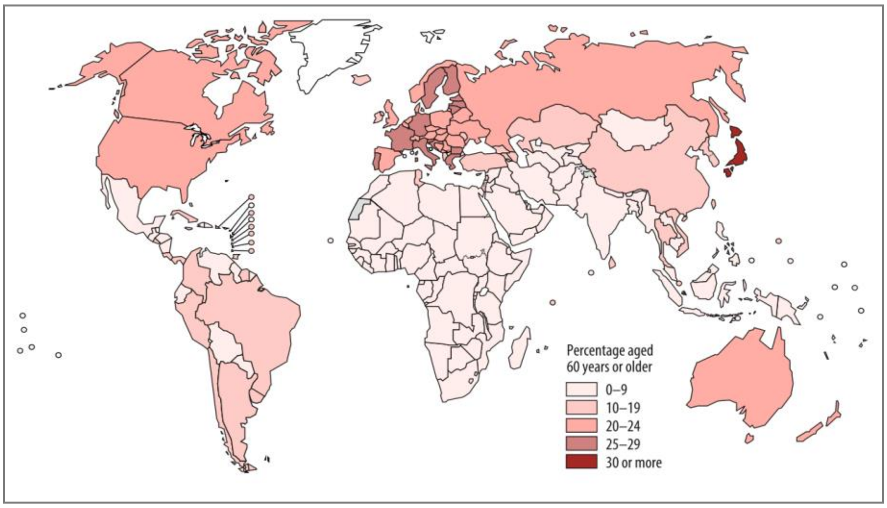


Figure 2.1: Proportion of population aged 60 years or older, by country, 2015
Source: WHO, 2015

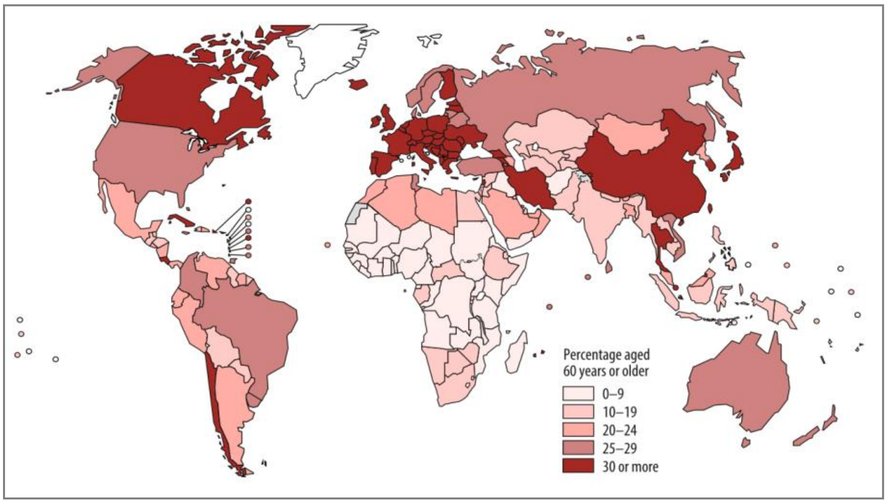


Figure 2.2: Proportion of population aged 60 years or older, by country, 2050
Source: WHO, 2015

2.4: Ageing Population in the KSA

The ageing population is a potentially major issue for the Government of the KSA, in respect of access to healthcare services. With the country experiencing growth in the economic and health sectors, the ageing population will incur health challenges if measures to address the situation are not taken into consideration (Altamimi, 2016; Alsulami & Atkins, 2016). The proportion of people aged below 15 years in the KSA has declined from 49.23% to 28.6% from 1992 to 2015. It is expected that their number will drop to 18.7% in 2050 because of the reduction in fertility and mortality (United Nations, 2015d, 2015b).

In contrast, the projections by the United Nations Department of Population estimate that the population of the aged in the KSA is expected to increase. In 2015, the KSA ageing population was 5% (1.5 million) and the median age was 28.3 years. By 2030 it is projected to be 11.1% (4.3 million), and the median age will be 32.3 years. Furthermore, by 2050 the number of elderly people is expected to increase to 9.6 million, 20.9% of the total population, with a median age of 38.2 years (United Nations, 2015d, 2015b).

The United Nations (2015d) has indicated that the current and projected age groups in the KSA are distributed as illustrated in Figure 2.3.

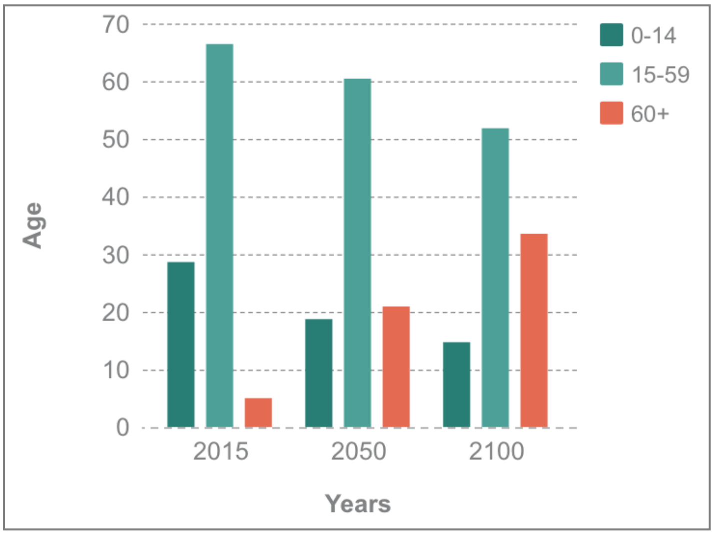


Figure 2.3: Age Group in KSA
Source: United Nations, 2015

The total dependency ratio (e.g., the sum of the total population aged 60 and over plus the total population between 0 and 15, divided by the population aged 15 to 60 (World Health Organization, 2002) in the KSA was 72% in 2000 and decreased to 45.6% in 2015. It is expected to fall, mostly due to the reduction in child dependency, until it reaches 36% in 2030. It is expected to rise again in 2050 to reach 52.2% due to the increase in old-age dependency and reach 81.1% by 2100 as presented in Figure 2.4 (United Nations, 2013b).

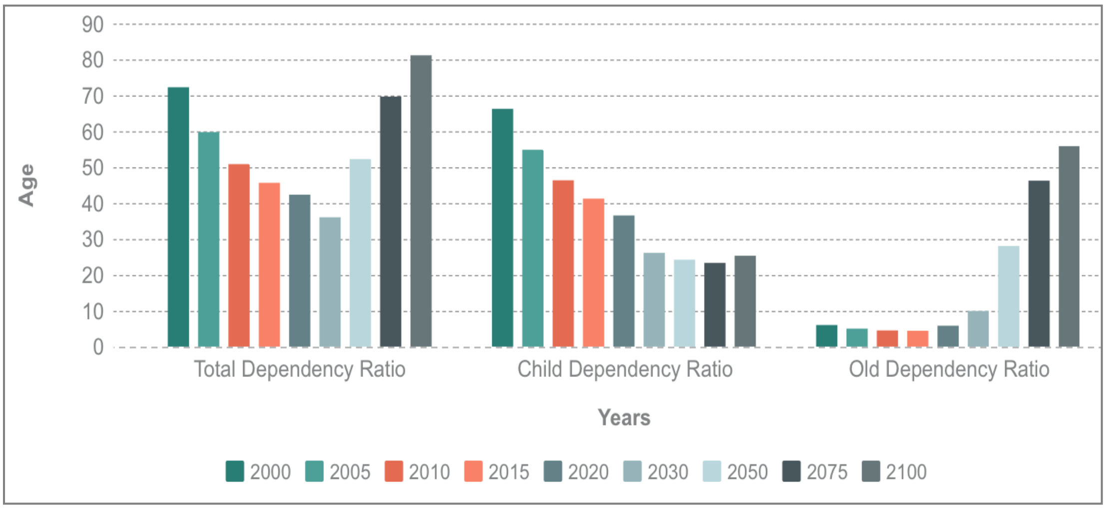


Figure 2.4: Total Dependency Ratio in KSA
Source: United Nations, 2013

2.5: Causes of increases in the Ageing Population

Significant research and studies have distinguished three factors as the causes of increases in the ageing population. These are fertility, mortality and international migration (United Nations, 2015b; He et al., 2016; Government Office for Science, 2016).

2.5.1: Fertility

One major cause of increases in the percentage of ageing populations is a reduction in fertility, e.g., in the total number of children per woman, which is evidenced through demographic change. The fall in the number of births decreases the size of the younger age groups, as compared to the past and to older groups, and consequently they become a smaller percentage of the total population. This automatically increases the complementary percentage of people in the older age groups, and in particular of the ageing groups, which embody the high fertility of the past. Therefore, worldwide, the proportion of elderly people is growing more rapidly than for other age groups (United Nations, 2015b; Government Office for Science, 2016; He et al., 2016) .

The United Nation indicated that, in 2015, the number of people with an age of 60 and over was 48% higher than in 2000, worldwide. In addition, it is expected that the number of elderly people will have doubled that of 2015 in 2050, to reach 2.1 billion people. In contrast, in 2050, the number of people in the age groups under 10 years and 10-24 years is estimated to decrease by 20%, compared with 2000.The age group 25-59 years will increase rapidly compared with the number of children, but not as much as the number of elderly people. It was noticed that, in 2015, the age group 25-59 years was larger than in 2000, and it is projected to increase by 63% in 2050 (United Nations, 2015b).

In the last few decades, it became clear that the first demographic changes occurred in Europe and Northern America, where the reductions in fertility shaped the population's age structures. Recently, Africa has the highest reduction in fertility: it will decrease from 4.4 in 2015 to be 2.8 by 2050 as shown in Figure 2.5 (Thompson et al., 2013; Guerin et al., 2015; World Health Organization, 2015; United Nations, 2015b; Government Office for Science, 2016; He et al., 2016).

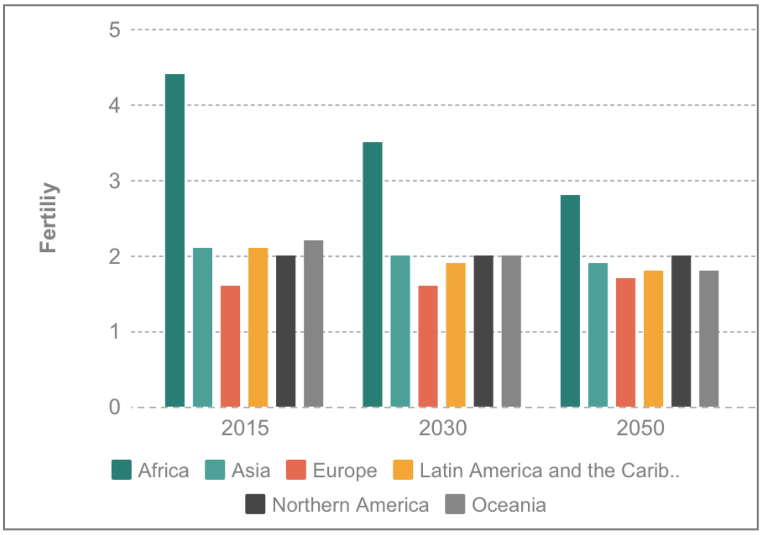


Figure 2.5: Total Fertility Rate by Region: 2015, 2030, and 2050
Source: World Population Prospects: The 2015 Revision. New York, United Nations

In the Middle East and North Africa (MENA) region, the total population is increasing, and the ageing population is also rising, which leads to an increase in health costs (Parkash et al., 2015). Some MENA countries show a reduction in fertility, for example, in Egypt, where fertility is in decline from 3.1 children per woman in 2000-2005 to an estimated 1.84 by 2095-2100. In Qatar, fertility was 2.95 in 2000-2005 and it is estimated that it will be 1.81 in 2095-2100. In Iraq, there will be a sharp decline from 4.75 to 1.97 by 2095-2100. In the KSA, the projection indicates that the fertility rate is decreasing from 4.51 children per woman in 2000-2005 to an expected 1.81 in 2095-2100 (United Nations, 2013b).

In 2015, the crude birth rate (per 1,000 population) in the KSA was 21, which is considered lower than the regional (31.4) and global (24.3) rates (Ministry of Health, 2015). There are some factors that reduce the birth rates in some Middle Eastern countries, such as urbanisation, female employment and higher levels of education (Norville et al., 2003). In the KSA, experts have identified the reasons for the reduction in fertility as a later marriage age for both men and women, a high cost of living and growing abortion (Arab News, 2015).

In the KSA, the projection by the United Nations indicates that the fertility rate is decreasing sharply from 5.5 children per woman in 1990-1995 to an expected 1.8 in 2045-2050. This number will keep dropping to 1.79 from 2095-2100, as illustrated in Figure 2.6 (United Nations, 2015d).

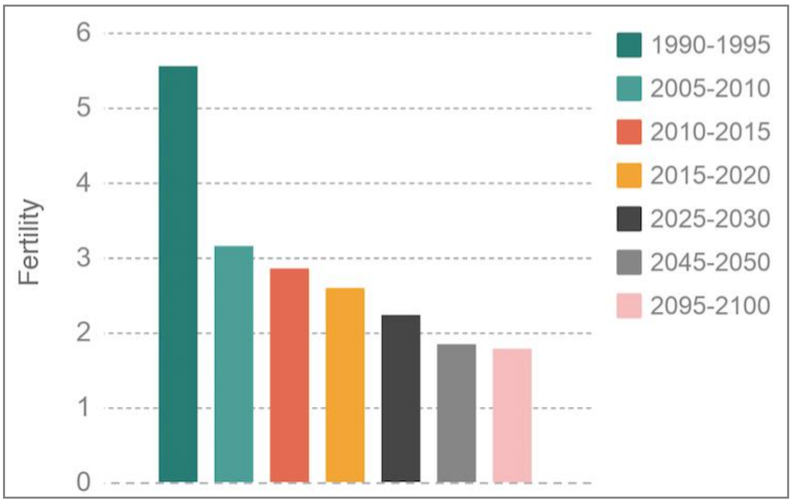


Figure 2.6: Total Fertility in KSA (average number of children per woman)
Source: World Population Prospects: The 2015 Revision. New York, United Nations

2.5.2: Mortality

The second and most important cause of an increasingly ageing population is the improvement in life expectancy at birth that is determined by a reduction in mortality (United Nations, 2015b; He et al., 2016; Government Office for Science, 2016; World Health Organization, 2015; Guerin et al., 2015).

The number of elderly people has increased because the mortality rates have dropped and people live longer (United Nations, 2015b; Government Office for Science, 2016; Khan et al., 2013; Leeson, 2016). Worldwide, life expectancy is projected to increase from 70 years in 2010-2015 to be 77 years in 2045-2050, and to 83 years in 2095-2100 (United Nations, 2015d).

By 2050, worldwide life expectancy at birth is expected to increase by approximately 8 years to reach 76.2 years (He et al., 2016). On average, in 2010-2015 elderly people aged 60 years are estimated to live 20.2 years longer. Figure 2.7 illustrates how worldwide life expectancy at age 60 changes over time (United Nations, 2015b). In Japan, for example, the life expectancy will increase from 84.7 years in 2015 to 91.6 years in 2050. In Nigeria, it will extend from 53 years in 2015 to 68.1 years. In Canada, it will change from 81.8 years in 2015 to 83.9 years in 2050 (He et al., 2016).

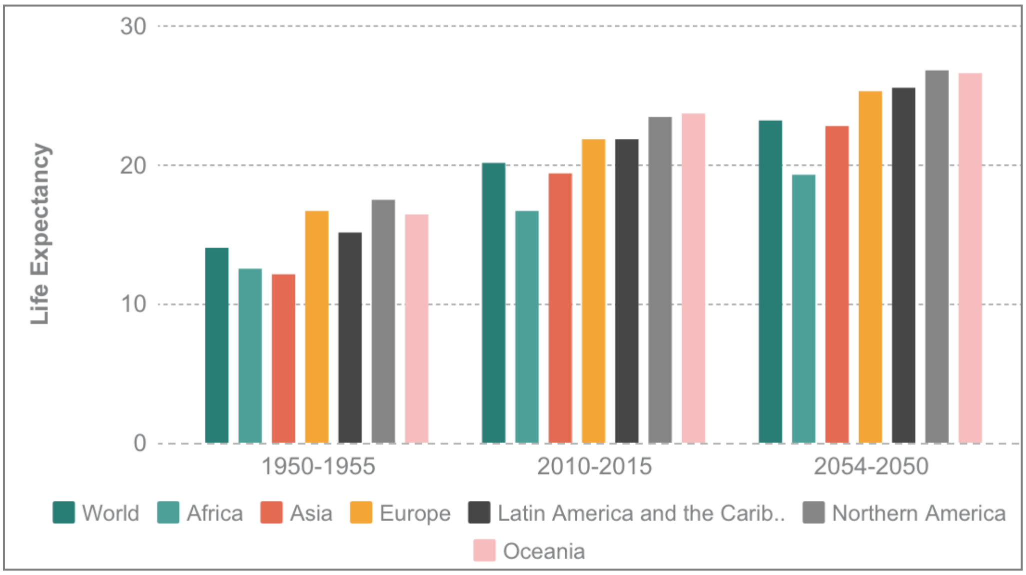


Figure 2.7: Life Expectancy at Age 60
Source: World Population Prospects: The 2015 Revision. New York: United Nations

A global percentage distribution of the population in selected age groups is presented in Figure 2.8 (United Nations, 2015d).

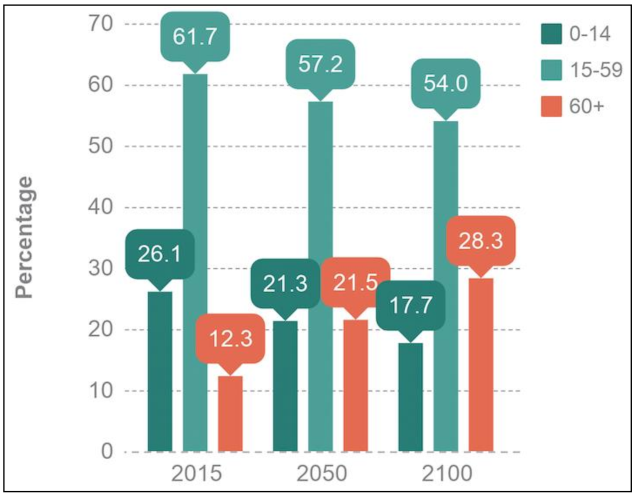


Figure 2.8: Global Percentage Distribution of the Population in Selected Age Group
Source: World Population Prospects: The 2015 Revision. New York, United Nations

In the MENA region, the total population has increased, which includes increased numbers in the ageing population. Therefore, the family structures and the options of care for elderly people will consequently change in the future (Parkash et al., 2015). Because of the reduction in mortality and improvements in the healthcare system, women in the MENA region live longer and healthier lives, and their life expectancy has risen by 10 years (World Bank, 2013). Their average life expectancy has increased from 48.7 years in 1965 to 70.4 years in 2010. It is expected to increase to 76.9 years by 2045-2050 (Hussein, 2016), which is lower than the overall Saudi life expectancy (81.8 years) (United Nations, 2013b).

In the KSA, life expectancy was approximately 70 years in 1950, but in 2010, it had increased to 74 years, and it is expected to reach 85.3 years by 2100 as shown in Figure 2.9 (United Nations, 2015d).

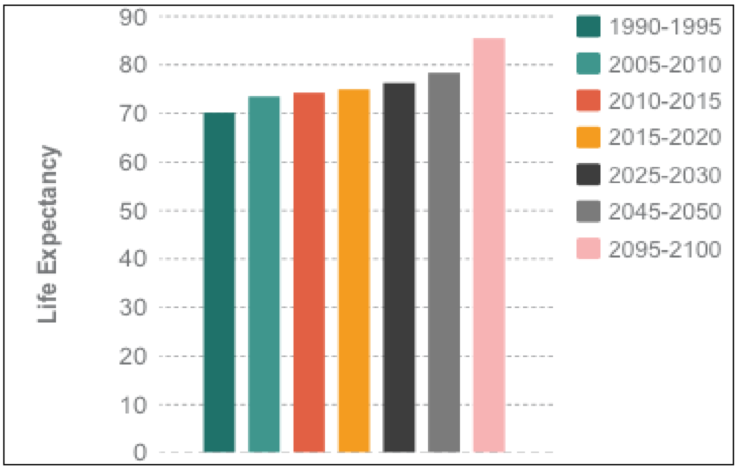


Figure 2.9: Life Expectancy in KSA
Source: The 2015 Revision. New York: United Nations

2.5.3: International Migration

International migration has influenced the ageing population structures in many countries. A high level of immigration can affect the age structures of the population (United Nations, 2015b; He et al., 2016). It was observed that the number of countries that intended to increase the proportion of immigrants has risen from 8 in 1996 to 22 in 2013, and 20 out of the 22 countries (91%) had concerns about ageing populations in 2013 (United Nations, 2015b).

The United Nations indicated that international migration could affect the size of the ageing population, based on either the projected net migration of working age people or the net immigration of elderly people, or both (United Nations, 2015b).

Labour immigration to the KSA can be traced back to the late 1930s, due to the need to explore for oil. In 2012, the Saudi Government announced that the number of non-Saudis was 9.7 million, and up to 5 million of them were illegal immigrants, due to visits to the two holy mosques (Bel-Air De, 2014).

The workforce eligibility is available for both Saudis and non-Saudis. Non-Saudis are required to obtain approval from the Ministry of Labour and Social Development before arriving in the KSA. The KSA provides a sponsorship system that allows international workers to enter, work, and leave the KSA, through their sponsors' approval. The workers have to undergo a medical test, and then apply for an entry visa. After that, the visa is issued by the KSA embassy in their countries. When the visa is issued, the workers are allowed to enter and work in the KSA, and then an Iqama (Identity card and residency visa) is issued. Once the workers arrive in the KSA, they are required to be fingerprinted and have an eye cornea scan. The employers must register their international workers with the General Organisation for Social Insurance (GOSI). In order for workers to move to another employer, they have to get approval from the previous employer (L&E Global, 2017).

Since 2000, the population of the KSA has risen annually by 3% because of the increase in the expatriate population. In fact, the number of expatriates has grown annually by 4% since 2000, while the number of Saudis increased by 2% (Ministry of Labor and Social Development, 2016).

The KSA is experiencing a major economic transformation, creating new wealth, and this growth needs more labour. Therefore, the KSA has welcomed international workers, and this has led the number of migrants to exceed the number of Saudis in the labour market. Overall, the unemployment rate is 5.6%, but Saudis' unemployment stands at 11.5%. Thus, the Saudi Government has established many programs to increase the employment of Saudis, such as the Nitagat program in the private sector. While the private sector is growing, unemployment amongst Saudis is still high, especially among young people, at more than 39% in 2015 (Ministry of Labor and Social Development, 2016).

Hence, the Saudi Government has identified five major challenges that face Saudi employment: lack of competitiveness to fulfil private sector jobs, reliance on foreign labour, high youth unemployment, inefficient job placement and matching, and the low rate of female labour participation in the market. It is noticeable that foreign workers dominate, at 83%, the private sector workforce (Ministry of Labor and Social Development, 2016). International migration into the KSA is increasing and, in 2000, there were 5 million migrants, reaching 10 million in 2015, comprising 32% of the population (United Nations, 2015a). In the second half of 2015, the Saudi General Authority for Statistics reported that the total number of employed people was 11.5 million, of whom almost 6.5 million were non-Saudi (56%), as illustrated in

Table 2.3 (Saudi General Authority for Statistics, 2016). Data for 2010 are not provided.

Table 2.3: Non-Saudi Employment (in thousand)

Age Group	2007	2008	2009	2011	2012	2013	2014	2015
	Comparison of Second Half of Each Year							
15-19	21,021	21,609	20,990	28,545	31,972	33,309	30,544	27,307
20-24	188,270	171,891	158,944	217,027	231,055	229,020	220,477	247,007
25-29	623,651	598,545	539,860	604,295	620,608	557,340	522,355	534,755
30-34	964,974	995,382	990,635	1,200,530	1,239,905	1,090,637	1,012,805	989,487
35-39	868,218	908,809	954,306	1,329,823	1,358,336	1,375,283	1,413,808	1,435,893
40-44	636,262	672,602	700,139	1,000,843	1,040,098	1,091,376	1,162,341	1,291,995
45-49	416,568	433,243	455,912	665,719	688,484	741,267	809,462	880,964
50-54	245,393	258,685	274,331	405,692	416,627	462,670	501,978	556,013
55-59	114,776	130,365	143,495	222,612	229,687	262,092	289,024	326,003
60-64	40,585	44,908	49,753	81,174	92,783	119,598	127,209	157,459
65+	23,882	24,592	21,659	36,203	43,398	49,404	51,486	61,668
Total	4,143,600	4,260,631	4,310,024	5,792,463	5,992,953	6,011,996	6,141,489	6,508,551

Source: (Saudi General Authority for Statistics, 2016)

2.6: The impact of an Ageing Population

The ageing population presents many challenges for the world. The increased life expectancy and the reduction in the birth rate have many consequences, which can be clarified as follows:

2.6.1: Economy

2.6.1.1: Pensions

The lower rate of mortality applies to all age groups and, over time, feeds larger numbers into the ageing group. The increased (and still increasing) life expectancy increases the number of years people survive in the ageing group, and the number of people reaching very old ages. Both aspects have a great influence on pensions and on healthcare. The effects on pensions have created a crisis situation worldwide, for both governments and private pension schemes.

The increasingly ageing population causes an increasing pressure on governments to provide and finance appropriate retirement benefit schemes. As a result of the growing numbers of beneficiaries, and of the fact that they draw their benefits for a much longer time than expected and budgeted years before, there is a need to increase the reserves of social security benefit, to ensure that the amount of money available is sufficient to provide for all the beneficiaries. The governments also need to ensure that the funding is sustainable, and they need to set up appropriate measures to ensure continued availability of the benefits, as this ‘will not be a one-time need’ requirement. Therefore, this will affect government budgets, as they need to allocate larger amounts to the retirement benefit scheme. This means that further contributions will need to be taken from taxpayers as they are the main sources of government revenue (United Nations, 2015b; World Health Organization, 2015; Government Office for Science, 2016; He et al., 2016; Bauer et al., 2015).

In the KSA, the ageing population will increase pressure on government debt and public finance over the coming decades (Standard & Poor’s Financial Services LLC, 2016). As the proportion of elderly people (above 60 years) increases, there will be more people eligible for pension benefits (Abusaaq, 2015). In 2015, the total number of employees at age 60 years and above was 160,860 thousand (Public Pension Agency, 2015). The retirement age is determined by the Saudi Government as 60 years. However, employees are now allowed to continue to work after they reach 60 years of age. The Public Pension Agency (PPA) calculates the benefits according to the years of service, which, in order to get full retirement benefits should be 40 years worked before reaching 60 years of age. The PPA deducts 9% from employees’ payroll during their working life. The normal retirement pension can be calculated as the number of worked years before the age of 60 multiplied by 1/40th of the final salary of the retiree, when he/she is eligible for retirement benefit. Particular regulations apply to people retiring for special reasons, e.g., health (Alazzam, 2016).

In 2015, the total number of retirees was 710,672, which includes all cases of retirement, of which 532,117 are alive and 178,555 are deceased. The total amount that was paid by the government to the retirees or their dependents was SR 54,897 million in 2015, and the total amount that has been paid since the establishment of the PPA is SR 561,185 million (Public Pension Agency, 2015).

2.6.1.2: Workforce

Elderly people, in some cases, require people to take care of them, especially if their age and health has affected their mobility. In these circumstances, caregivers are assigned to support them, either at their homes or at social care homes, and, therefore, new job opportunities are created for the workforce. Research worldwide shows that the number of those above 65 years will double by 2030, meaning that there will be more demand for caregivers (Strulik & Werner, 2012; Government Office for Science, 2016). Therefore, in the KSA there is a need to fill the gaps, by 2030, in the nurse shortage with 100,000 more nursing positions, and, overall, 710,000 more healthcare professionals (Mckinsey Global Institute, 2015).

In the KSA, the ageing population (over 60 years) will significantly rise to 20.9% in 2050, which will lead to a decrease in the number of working people and could result in wage inflation. Furthermore, the total Labour Force Participation Rate (LFPR) is expected to fall from 53% in 2010 to 48.6% in 2050 (Abusaaq, 2015). This will cause shortages in all sectors of activity but will be particularly acute in the healthcare sector. One of the biggest challenges facing Saudi healthcare providers is the shortage of local healthcare professionals, such as pharmacists, nurses and physicians. The majority of the health workforce are immigrants (Almalki et al., 2011; Safi, 2016). In 2015, the total number in the health workforce was 282,865 employees; 86,756 physicians (26% Saudi), 23,626 pharmacists (21% Saudi) and 172,483 nursing staff (38.3 % Saudi) (Ministry of Health, 2015).

2.6.2: Healthcare

The increase in life expectancy will result in increasing healthcare costs per person: as people get older they need more healthcare supports. Elderly people are susceptible to a number of illnesses and infections, as a result of weak bodies and immune systems. This results in the ageing population requiring more investment in healthcare to support them. According to a report by the WHO, by 2030, 60% of those above 65 years of age will be affected by one chronic disease. Despite the significant increase in the proportion of elderly people, the healthcare system is not currently designed to address the increasing demand for providing appropriate healthcare services for their needs (United Nations, 2015b; World Health Organization, 2015; Government Office for Science, 2016; Khan et al., 2013).

In the KSA, as a result of the ageing population increase, the expenditure on healthcare will grow as well (Abusaaq, 2015). More details are provided in Section 2.5.5.

2.6.3: Family

As people become older, in some cases they are no longer able to live alone, provide for themselves or do certain things, such as cooking, shopping, etc., because of their increased inability to move around. In many cases, this burden is shifted to their relatives, and, therefore, their families have to spend extra money and time taking care of them. Thus, a changing population structure has created more responsibilities for families, with the consequent need to work more, to meet this extra duty (Government Office for Science, 2016; United Nations, 2015b; He et al., 2016).

In the MENA region, the total population has increased, which has led to an increase in the ageing population. Therefore, the family structures and options for the care of elderly people will change (Parkash et al., 2015). In the KSA, the most common situation is that the oldest son/daughter takes care of their parents, although this is not always the case. The second most common option for wealthy children is to hire staff in order to take care of their family. A third option, for poor children is that they may apply for financial support to provide their parents with their needs. A fourth option is that non-governmental organisations can provide support for elderly people. Lastly, the government can accommodate elderly people in social care homes and provide them with an acceptable quality of life (Al-shabani, 2005). The KSA Ministry of Health currently provides 33,813 beneficiaries with social home healthcare from 180 hospitals (Ministry of Health, 2013b). A study has indicated that the majority of people who benefit from social home healthcare are the elderly, in order to be provided with a good quality of life (Alanazi, 2014). Unfortunately, to the best of our knowledge, there are no statistical data about the family roles regarding their elderly relatives.

2.6.4: Consumer Spending

As a result of changing needs due to changing population structure, consumer-spending is also changing. This is because customers of different age groups demand different types of goods and services. Consequently, consumer spending for consumables is affected by changes in the consumers' age structure and particularly by the larger percentage of people in the ageing population (ATKearney & Consumer Goods Forum, 2013; Financial Conduct Authority, 2016). In the KSA, elderly people have traditionally saved less and consumed more, due to their needs and lifestyle (Abusaaq, 2015).

A particularly important change is in the housing market. As people get older, many of them are, sentimentally and for other reasons, attached to the house/apartment where they have lived for many years and do not want to move to a smaller one, even after their grown-up children have moved away and formed new households. Consequently, a larger percentage of people in the ageing population results into an average smaller number of inhabitants per house/apartment, and hence the need for more houses/apartments to be built. This, added to the extra housing needed for immigrants and for young people moving to larger towns, has created a housing problem, fast increasing house prices, and even a crisis situation, in several countries (Savills World Research, 2015).

2.7: Healthcare in the KSA

The KSA is the largest country in the Arabian Peninsula. The population of the KSA is 31 million, and the capital city is Riyadh, with a population of 7.7 million as of 2015 (Saudi General Authority for Statistic, 2015).

The Ministry of Health (MOH) in the KSA is the main provider of healthcare services. The MOH provides Primary Health Care (PHC) facilities and services throughout a network of healthcare centres. The Saudi Government provides citizens and residents with free access to health services through the public sector. The health system consists of three levels: primary, secondary and tertiary healthcare. In addition, there are some private hospitals, where citizens have to pay for e treatment (Almasabi, 2013; Almalki et al., 2011; Alshahrani & Raheel, 2016) or which can be covered by their employers (Ismail, 2015).

According to the Saudi Arabian Ministry of Health (2015), the KSA has experienced extensive growth in its healthcare system through improvements in staff training, quality of care and integration of modern technology in the health sector. From 1970 to 2015, the KSA has increased its number of hospitals from 74 to 462, with the number of beds increasing from 9,039 to 69,394 in the same period of time.

In 2015, the number of beds in the MOH was 41,297 in 274 hospitals. This accounts for 58.5% of hospitals, and the remainder are governmental (11,449) and private sector (16,648). The total number of Primary Healthcare Centres (PHC) was 2,282 across the country (Ministry of Health, 2015).

The government allocated SR 62 billion (US $16.5 billion) in 2015 for improvements in healthcare services. Table 2.4 presents the budget appropriations for the MOH in relation to government budgets from 2010 to 2015 (Ministry of Health, 2015). In 2010, the average expenditure per capita was US $345 (Almasabi, 2013). In 2013, the expenditure per capita was reported as US $808, which is considered double the average per capita health expenditure in the MENA region (Ismail, 2015).

Table 2.4: KSA's Budget Appropriations for the MOH in Relation to Government Budget by (1,000 SR)

Year	Government Budget	MOH Budget	Percentages
2010	540,000,000	35,063,200	6.49%
2011	580,000,000	39,860,200	6.87%
2012	690,000,000	47,076,447	6.82%
2013	820,000,000	54,350,355	6.63%
2014	855,000,000	59,985,360	7.02%
2015	860,000,000	62,342,539	7.25%

Despite the massive budget allocated to the health sector by the Saudi Government, there are challenges in the provision of health services in the KSA. Some of these challenges can be summarised as: health workforce (Almasabi, 2013; Almalki et al., 2011; Safi, 2016); rapid increase in expenditure; pilgrim services; about 5 million pilgrims every year; (Almasabi, 2013); health insurance; privatisation of hospitals; diversifying financial sources (Almalki et al., 2011); language; cultural effects and prevalence of chronic diseases (Safi, 2016). However, in 2016, the Saudi Government announced its 'National transformation program 2020' which includes some initiatives by the Ministry of Health, which is planning to invest more than SR 23 billion in its new initiatives to achieve its 'vision 2030' (National Transformation Program, 2016).

The Ministry of Labour and Social Development is accountable for taking care of elderly people (aged over 60 years) who are unable to live independently and are not supported by their family. The Social Care Home is a department of the Ministry of

Labour and Social Affairs, and its role is to provide elderly people with quality of life, including full healthcare for those who cannot be accommodated by their families. Currently, there are 12 social care homes in the KSA, which are located in Riyadh, Madinah, Makkah, Abha, Taif, Damam, Onizah, Jouf and Wadi Al Dawasir (Planning and Development Directorate, 2016).

2.8: Health Issues Related to the Ageing Population

Many people face a decline in their health when they become older and need some support in their daily activities, as well as facilities to monitor their health (Hossain et al., 2014; Al Saif et al., 2012; Blasco et al., 2014). The World Health Organization reported that non-communicable diseases are common among elderly people, including heart disease, dementia, cancer, and chronic respiratory disorders. In general, elderly people are vulnerable to loss of sight, hearing and mobility (World Health Organization, 2015).

In the United States (USA), by 2030, it is projected that more than 8 million people will be diagnosed with heart failure (HF). The cost of HF treatment in 2012 was US $31 billion, and it is estimated to reach $70 billion in 2030. The proportion of the total HF expenditure for people who are 65 years of age and older is expected to increase from 69% in 2012 to 80% in 2030 (Heidenreich et al., 2013).

In the US, in 2009, 75% of patients who were hospitalised for HF were 65 years and older, and the cost of treatment was US $37.2 billion (Samala et al., 2011). In the United Kingdom (UK), cardiovascular disease (CVD) was the second leading cause of death, accounting for 28% of fatalities in 2014. The cost of treating CVD in England was more than £6.8 billion in 2012 (Townsend et al., 2014). HF is a major concern for elderly people in the KSA (AbuRuz et al., 2015; Albugami et al., 2015).

In Canada, 15% of elderly people suffer from depression, and it is expected that the number of Canadians with dementia will increase from 500,000 to 1.1 million by 2030. Respiratory illnesses are very common among elderly people. Yearly, the cost of lung diseases is CAD $15 billion, and it is projected to rise to CAD $27 billion by 2020 (Smith, 2012).

In Ireland, the proportion of elderly people who suffer from chronic diseases such as diabetes, heart disease, musculoskeletal pain and hypertension, is expected to rise to 40% by 2020 (Age Action Ireland, 2013).

In Australia, a study reported that the most common health issues among elderly people are arthritis (49%), hypertension (38%), hearing loss (35%), heart stroke and vascular diseases (22%) and, diabetes (15%) (Australian Institute of Health and Welfare, 2014).

In the KSA, roughly 20.7% of elderly people show up at PHC facilities, and many fail to receive a proper diagnosis. The study showed that each elderly person had two or more diseases (Al-Doghether, 2004). A study was conducted by (Al-Modeer et al., 2013) and indicated that the most relevant health issues for elderly people are hypertension (59.1), diabetes mellitus (57.3%), stroke (34.9%) and dementia (28.5).

Another study conducted in Northern Saudi Arabia with 181 participants (aged 60 years and above) found that elderly people experience difficulties in their health, and they require more care and better prevention systems (AboEl-Fetoh et al., 2016).

A study conducted in 2013 in the KSA for 10,735 participants over 60 years of age showed that 45.8% take medication (Moradi-Lakeh et al., 2015). A survey of 2,095 (350 of whom were 60+) participants demonstrated the high percentage of risk of Obstructive Sleep Apnea (OSA) among the elderly (≥60 years), which was 41% (Alruwaili et al., 2015). On some occasions, this leaves elderly people unable to obtain placement in beds at hospitals (Ministry of Health, 2013a).

These challenges and issues require novel approaches for dependable self-adapting technological innovations. Ambient Assisted Living (AAL) is advocated as a potential form of technology, which can involve assisting and helping elderly people to overcome these challenges, and to meet the requirements of individuals as the needs and circumstances of the elderly change.

2.9: Conclusion

The world population is increasing, and it is projected that its size will reach 8,501 million by 2030. The ageing population is also increasing fast and will comprise 16.5% of the world population by 2030. The challenge of the ageing population in the KSA was still manageable in 2015, but it may become uncontrollable in the future, due to the dramatic growth in the proportion of total population who are old. In the KSA, this proportion will rise from 5% in 2015 to 33.5% by 2100. Fertility, mortality and international migration are singled out as the main causes of an increasingly ageing population. Despite the efforts and bold steps taken by the government, the growth of the ageing population puts unsustainable pressures on pensions, healthcare, family and consumer spending in particular.

This chapter has shown how the KSA's aging population problem fits into the worldwide framework, and how the problem is likely to increase over the short, medium and long term. It has also introduced the present situation in the KSA, regarding, in particular, the provision of pensions and healthcare, and pointed to the necessary developments. Such developments must cope with the needs of the elderly, and this chapter finishes by presenting figures on how elderly people suffer from many diseases that have a particular effect on their lives. These non-communicable diseases are common among elderly people and include arthritis, heart disease, dementia, cancer, hypertension, diabetes mellitus, stroke, and chronic respiratory disorders. Furthermore, elderly people are vulnerable to loss of sight, hearing and mobility.

Chapter 3 discusses the history and definition of Ambient Assisted Living (AAL), reviews AAL technology that is provided, identifies the barriers facing the deployment of AAL, and the benefits of AAL that are delivered to elderly people.

Chapter 3: Ambient Assisted Living

3.1: Introduction

Chapter 2 reviewed the ageing population worldwide and in the KSA and outlined the impact of its increasing percentage. We found that there are three causes for the changes in numbers and percentages of the ageing population, which are reduction in fertility, mortality and international migration. The impact of the ageing population on the economy was further discussed in terms of healthcare provision, family responsibility and consumer spending. This impact will contribute to pressure on governments to provide suitable technological solutions to support elderly people with an acceptable quality of life.

The ageing population is increasing dramatically, globally and in the KSA. Therefore, solutions are needed to assist elderly people to live longer and independently, be safer and secure and assist them in some of their daily activities. In this chapter, we will introduce the background and definitions of Ambient Assisted Living (AAL), quality of life and independent living. In Section 3.3 a review of AAL technology is introduced, including Smart homes, assistive robotics, mobile and wearable sensors and e-textiles. Using AAL technologies can provide elderly people with some benefits that facilitate independent living, assisting them with daily activities and improving their health.

This chapter also includes the definition of the Internet of Things (IoT) and Smart city as a complementary technology to AAL. It identifies the challenges that affect the adoption of these technologies and their relationship to AAL.

3.2: Ambient Assisted Living (AAL)

The emergence of Ambient Assisted Living (AAL) dates back to the 1990s and started to be considered by the middle of the 2000s (Garcés et al., 2017). AAL '*relates to intelligent systems of assistance for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment, with the aim of enhancing the quality of life for all elderly people in all stages of their life*' (AALIANCE2, 2014).

In addition, AAL is considered to be a technological innovation that is intended to improve the life quality of the elderly and has the capability to support their requirements in their later years through the application of technology (Ansari et al., 2014). It is developed through automation of homes, and through assistive domesticity. It provides people in this age group (elderly) with assistance in carrying out their daily activities, prolonging their life expectancy, and improving their social life and communication (Blasco et al., 2014).

Quality of Life (QOF) can be defined as '*an individual's perception of his or her position in life in the context of the culture and value system where they live, and in relation to their goals, expectations, standards and concerns. It is a broad ranging concept, incorporating in a complex way a person's physical health, psychological state, level of independence, social relationships, personal beliefs and relationship to salient features in the environment*' (WHO, 1994). As people become older, their quality of life can be determined by their ability to retain autonomy and independence (World Health Organization, 2002).

The International Summit Conference on Independent Living in 1999 adopted what is known as the Washington Declaration. This states that '*..... all human life has value and ....every human being should have meaningful options to make choices about issues that affect our lives. "Independent living" is therefore closely associated with the words "choice and control" and is usually applied to both the environment in which someone lives and the assistance they might need in order to go about their daily lives*' (Morris, 2003).

AAL is an innovative form of technology that can be used to provide elderly people with quality of life, to live longer and independently (Rghioui et al., 2016; Marques & Pitarma, 2016), to monitor and assist elderly people (J.Bellmunt et al., 2016; Calvaresi et al., 2016), and to provide them with social communication (Sánchez-Pi Rio et al., 2016). It has the capability to support their requirements, as they age, through the application of technology (Ansari et al., 2014).

The overall goal of AAL solutions is to employ the Ambient Intelligent (AmI) concept and technologies to empower elderly people with specific needs, to improve their quality of life, to support their daily activities, to live longer in their domestic environment, and to remain at home independently (Queirós et al., 2015).

The Ambient Assisted Living European Joint Programme (AALIANCE2) was launched in 2008 (AALIANCE2, 2014) and is funded by the European Commission. It centres on Ambient Assisted Living (AAL) solutions for ageing that depend on advanced Information and Communication Technologies (ICT). It planned to invest €1 billion in ICT to provide elderly people with a better quality of life (2008-2013) (Alberta Advanced Education and Technology, 2009).

Stakeholders for AAL are classified by AALIANCE2 (2014) as follows:

- The primary stakeholders include elderly people and their informal caregivers such as families. Elderly people are using the AAL technology and benefit from it by increasing their quality of life
- Secondary stakeholders include organisations that deliver services to elderly people who are in need of assistance such as service providers
- Tertiary stakeholders include organisations that provide services and goods such as industries producing AAL technologies
- Quaternary stakeholders include an organisation that provides analysis of the economic and legal context of AAL such as policy makers, insurance companies, etc.

AAL is considered to be an integration of the three core technology domains, and was proposed by (Kubitschke & Cullen, 2010) and adopted by (AALIANCE2, 2014). These three domains are organised as a technological space. The combined concept of long-term care services includes health, housing components and social components, and is realised as providing holistic and integrated services for elderly people. The three domains are Telecare, Telehealth and Smart homes as shown in Figure 3.1.

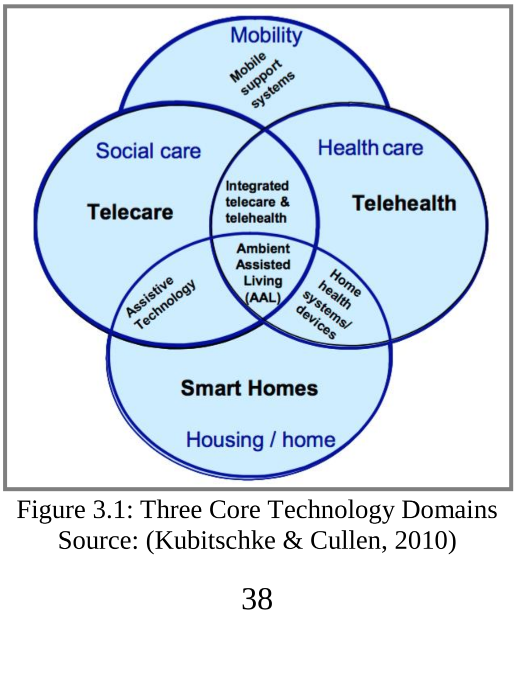


Figure 3.1: Three Core Technology Domains
Source: (Kubitschke & Cullen, 2010)

Kubitschke and Cullen (2010) described the three core technology domains as follows:

- Telecare refers to the use of telecommunication to provide at distance social care
- Telehealth is used to support independent living by providing services that deal with chronic diseases and health problems, which are related to increasing age
- Smart homes refer to 'domotics' technologies and applications, which include standalone devices that address specific requirements to completely combined Smart homes, via several forms of environmental control techniques.

3.3: AAL Technologies

Many technologies and projects have been designed and deployed as Smart environments that can assist elderly people to live independently (Grady et al., 2010). Recent AAL advancements include Smart homes, assistive robotics, wearable and mobile devices (Siegel & Dorner, 2017; Rashidi & Mihailidis, 2013; Jaschinski & Allouch, 2015) and e-textiles (Rashidi & Mihailidis, 2013).

3.3.1: Smart Homes (SH)

The origin of Smart home technology dates back to 1970s' home automation technologies (Hersh, 2015). A Smart home can be defined as a '*residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants*' (Balta-Ozkan et al., 2013). The concept of the Smart home is to allow facilities to provide home care for elderly people in an encouraging and cost-effective manner (Liu et al., 2016; Mageroski et al., 2016).

All Smart homes can be placed into different categories, depending on the equipment and systems installed. The main benefits of Smart homes are: improving healthcare, security, and safety, saving energy, ensuring comfort (Hafidh et al., 2017), monitoring health conditions, providing remote control and surveillance (Cai et al., 2016), controlling appliances and devices such as heating and lighting (Wilson et al., 2017), and assisting in performing daily activities (Pardo et al., 2016). For example, an assisted living Smart home provides elderly people with the help necessary to be independent; it can take action when unusual activities happen, such as contacting a nominated carer (Balta-Ozkan et al., 2013).

Many technologies and projects have been deployed and tested, such as the LOBIN project, which maintains the location and remotely measures the respiratory rate of elderly people in medical environments (Baig et al., 2013).

GatorTech Smart House locates its occupants and manages the environment, assessing their mobility in an attempt to improve lifestyle (Chan et al., 2012).

HOME project uses infrared and biosensors to deliver information to healthcare specialists about elderly people living in the house (Arshad et al., 2014). An example of a Smart home is shown in Figure 3.2.

A study conducted by Gfk (2015) for over 7000 consumers across 7 countries, the USA, Brazil, China, UK, South Korea, Japan and Germany, reported that 91% of consumers were aware of Smart homes. In addition, the global market share of Smart homes will grow from US $40 billion to US $58 billion by 2020. The study stated that security and control count for 55% of the consumers' needs, and the major barrier that limits their adoption is cost, for 36% of the study responses.

A study indicated that many investigations did not indicate the cost of technologies for a Smart home. However, the same study indicated that two studies it had investigated stated the cost was low. In addition, the same study mentioned that there is a study that said the cost was less than US $ 400, while another stated that the maximum cost of retrofitting a home was €13,500 (Morris et al., 2013).

Figure 3.2: An Example of Smart Home
Source: http://smarthomeenergy.co.uk

3.3.2: Assistive Robotic (AR)

Assistive robots can provide help with daily activities, such as bathing, eating, toileting, dressing (Linner et al., 2015), mobility (Zhou et al., 2017), navigating, delivering therapy and home maintenance monitoring (Broekens et al., 2009), rehabilitation (Song, 2016), walking-aid (Solis, 2016). Meng and Lee (2006) defined the assistive robot as a collaboration between a user and a device to perform some physical activities in the user's environment. Floor Cleaning Robots clean floors for elderly people (Patent & Office, 2013; Mateo Ferrús & Domínguez Somonte, 2016).

Mamoru is a robot that helps elderly people in their daily activities (Wu et al., 2012). ROBOT-ERA is a robot project that assists elderly people with daily activities (Broz et al., 2015).

These are just some examples of technologies that have been deployed and tested. An Example of assistive robotics is illustrated in Figure 3.3.

Figure 3.3: An Example of Assistive Robotic
Source: (Khosla et al., 2013)

3.3.3: Wearable and Mobile Devices (WMD)

A mobile health system is an application that monitors users' health. It uses biosensors to gather and analyse data. It is a terminal device that has an application installed to connect with a tele-monitoring service remotely (Morak et al., 2011; Guzik & Malik, 2016).

Studies have examined these mobile apps, such as Heart Saver, which is a portable medical device that monitors a real-time electrocardiogram (ECG) and detects cardiac pathologies.

MEDIC is a software architecture, which manages and enables sensor networks to predict diseases through PDAs and mobile phones (Baig et al., 2013).

OnkoNet is an agents-based architecture, which helps consumers to cope with the difficulty of using medical care services via mobile devices (Arshad et al., 2014). A wearable sensor is preferred for monitoring elderly activity recognition (Álvarez de la Concepción et al., 2016).

PlaIMoS is a low cost mobile system to monitor heart rate, blood oxygen, electrocardiogram, temperature, respiration, rate and fall data. It can be used either at home or in hospital (Miramontes et al., 2017).

Fall uses wearable devices to detect the fall and movement of elderly people (Sucerquia et al., 2017). An example is shown in Figure 3.4.

Figure 3.4: An Example of Mobile and Wearable Sensor
Source:http://healthfore.com

3.3.4: e-Textile (e-T)

Berglin (2013) described a Smart textile as a textile structure that responds to stimuli from its environment. The technique uses a monitoring unit to react to stimuli. However, in a more complicated situation, a processing unit can be used to increase its capability to analyse data. Sensors, actuators, and the controlling unit, are the essential parts of the Smart textile system. The main idea of Smart textiles is to design textiles with Smart accessories and computing power to assist users.

Many examples of these technologies have been implemented and tested; for instance, BIOTEX is a biosensor made using e-textiles, which assists elderly people to detect sodium, pH and conductivity; it also measures physiological parameters and the chemical composition of sweat (Baig et al., 2013). The MERMOTH project is a piece of clothing that measures skin temperature and respiration using a respiratory inductance plethysmography method (Pantelopoulos & Bourbakis, 2010). Figure 3.5 presents an example of an e-Textile.

Figure 3.5: An Example of e-Textile
Source: http://sportmondo-sportsportal.blogspot.co.uk/

3.4: Benefits of Adopting AAL technologies

Despite the factors that limit the adoption of technologies, many studies have shown that AAL technology could deliver many benefits to elderly people. The most important benefits elderly people gain by adopting AAL technology are:

3.4.1: Independent Living

AAL technology provides elderly people with a major benefit, which is to live independently, by increasing their autonomy and assisting them with daily activities. This is achieved by promoting the independence of elderly people in their own homes or preferred environment (Grgurić, 2012; Sun et al., 2009; Peruzzini & Germani, 2014; Blackman et al., 2016; Mainetti et al., 2016; Dasios et al., 2015).

3.4.2: Assisting with Daily Activities

One of the noteworthy benefits that encourage elderly people to adopt AAL technology is to make their lives more comfortable and enjoyable by assisting them with daily activities, such as dressing, washing, preparing food, cooking, drinking, walking, etc. These activities can support the elderly people's needs so that they can live independently and choose the activities that are appropriate for them (Rashidi & Mihailidis, 2013; Ruyter & Pelgrim, 2007; Dasios et al., 2015; Garcés et al., 2017; Zschippig & Kluss, 2016).

3.4.3: Improving Health

AAL technology promises to provide elderly people with services that can keep them in safe conditions by monitoring their movements, detecting falls, and preventing hazards. Many systems can assist elderly people to monitor requirements and conditions, such as with a reminder system for them to take a medicine, or turning off a stove, a microwave, etc. Video-based monitoring systems, monitor heart beats, etc. Therefore, the number of professional carers can be reduced, which leads to a lower cost of healthcare when AAL technology is considered as a backbone for healthcare providers (Memon et al., 2014; Arshad et al., 2014; Pantelopoulos & Bourbakis, 2010; Rashidi & Mihailidis, 2013; Arning & Ziefle, 2015; Bygholm & Kanstrup, 2015; Siegel & Dorner, 2017).

3.4.4: Social Involvement

AAL technology plays an important role in overcoming social isolation and loneliness by connecting the elderly with their families, relatives and friends. Connectedness is considered a main factor for a good quality of life. It allows elderly people to make friends through their social communication, and to strengthen their relationships. Finally, AAL technology helps elderly people to do some activities with a group that bring them happiness (Siegel & Dorner, 2017; Ting & Lewkowicz, 2015; Grgurić, 2012; Silva et al., 2016; Blackman et al., 2016; Sánchez-Pi Rio et al., 2016; Wong & Leung, 2016).

3.4.5: Safety

Elderly people are generally unprotected from dangers and threats. Therefore, AAL can provide elderly people with a safe environment (Chernbumroong et al., 2013). AAL can enhance their safety in their daily activities, such as when cooking (Yared & Abdulrazak, 2016). Smart homes are equipped with technology that monitors elderly people's health at home and keeps them safe (Demiris et al., 2004; Bisio et al., 2015; Wong & Leung, 2016).

3.5: Internet of Things

3.5.1: Origin and Definition

The term 'the Internet of Things' (IoT) can be traced back to 1999, when Kevin Ashton, the Executive Director of the Auto-ID Centre at the Massachusetts Institute of Technology (MIT), conducted research on the Radio-Frequency Identification (RFID) for manufacturers of consumer products. Within his study, this was originally done to track and count objects, but it was later realised that it had a much broader significance (Internet Society, 2015). Following the developments in technology since this research, between 2008 and 2009, the number of reported connected devices indicated that the concept of (IoT) was beginning to be implemented. This was shown by the evidence that the number of connected devices had increased from 500 million in 2003 to 12.5 billion in 2010, when compared to the population count that was 6.3 billion in 2003 and 6.8 billion in 2010 (Evans, 2011).

Furthermore, from what was originally a concept waiting for the technology to implement it, we now have the ability to connect to the Internet across multiple devices. This, coupled with innovations in transfer speed, now enables a ubiquitous presence of files, data and experiences for the user, irrespective of the device, purpose or location involved. Recent advances have enabled providers and manufacturers to implement devices with the capacity of interfacing with IoT technologically. However, despite this, such organisations and local government are still facing several barriers in terms of privacy, procedures and cross-platform integration that undermine the collective potential that such devices embody.

Although this emerging concept is widely recognised by users worldwide, the definition of 'the Internet of Things' is still disputed and appears to fall into five categories, depending on the purpose, user and device:

The first common definition is that of '*a global infrastructure for the information society that enables advanced services by interconnecting (physical and virtual) items based on existing and evolving interoperable information and communication technologies*' (International Telecommunication Union, 2012). In today's context, this information-focused approach to constructing a truly ubiquitous Internet of devices and services has already advanced significantly towards this end goal. However, as outlined in the following section, the surrounding difficulties in managing information from multiple devices and protocols is still a challenge for organisations seeking to maintain their current standard of information security.

Secondly, there is the definition of it as '*a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" are given identities; given physical attributes and virtual personalities; used in intelligent interfaces; and are seamlessly integrated into the information network*' (Vermesan & Friess, 2014). As with the former definition, while this approach to achieving an 'Internet of Things' has witnessed many advances over the course of the past two decades in creating intelligent and contextual representations of user information, the challenges of platform interoperability and privacy for the user still present challenges to implementing this definition.

The third definition '*refers to scenarios where network connectivity and computing capability extends to objects, sensors and everyday items not normally considered computers, allowing these devices to generate, exchange and consume data with minimal human intervention*' (Internet Society, 2015). While the systems to achieve this definition have been realised for certain devices on an individual basis, the competition between currently un-integrated platforms and services makes this a difficult feature to implement within this non-collaborative environment. However, as an increasing number of communication protocols and APIs become standardised, irrespective of the device platforms or manufacturers, so too will the functionality of cross-platform connectivity in every-day appliances.

The fourth definition pertains to '*connecting devices over the Internet, letting them talk to us, to applications, and to each other*' (The Guardian, 2015). As an approach to achieving the goal of full ubiquity, this approach again is dependent on the extent to which devices, services and users can seamlessly interact, irrespective of their manufacturer, platform or network. Regarding this fourth definition, although many advances have occurred organically over recent decades to the increasing standardisation of communication protocols and APIs across different platforms, the influence of competing platforms and device ecosystems means that the current 'Internet of Things' is undermined by the current absence of a collaborative environment.

Lastly, there is the definition of it as '*the vast network of devices connected to the Internet, which includes Smart phones and tablets, and almost anything that contains a sensor: such objects can be cars; machines in production plants; jet engines; oil drills; wearable devices; and more. Furthermore, these "things" are used to collect and exchange data*' (SAP affiliate company, 2016). As a concept, this definition could be considered to have been undermined in its current implementation by similar constraints as those for the other four definitions above. However, prior to identifying the possible barriers to collaboration between such technologies, it is necessary to develop an understanding of the different technologies and of the areas for which these approaches have most implications.

3.5.2: IoT Technologies and Domains

In 2014, the IoT market was valued at US $591.7 million and it is expected to increase to US $1.3 trillion by the year 2019 (Verizon, 2016). While many technologies are used in IoT, one study indicates that the following five technologies are the most commonly used:

Wireless Sensor Networks (WSN), IoT application software; Radio Frequency Identification (RFID), Cloud computing, and Middleware (Lee & Lee, 2015).

In the areas of application for IoT this can be considered as follows: Building Automation; Consumer & Home Automation,; Retail and Logistics; Healthcare and Life Science; Industrial; Transportation; Security and Public Safety, and Environment (Mounier et al., 2014). However, in-spite of this clear acknowledgment of the sensors, protocols and communications that are available to facilitate IoT, the challenges to implementing this concept have arguably shifted from the availability of such necessary devices, to the concerns, procedures, and interoperability necessary for them to function together.

3.5.3: Issues Related to IoT

In-spite of the enormous benefits that are delivered by IoT, there are still multiple barriers and challenges to its adoption. Among such issues are the implications for privacy and security, but also those of interoperability, due to the increasing variety of devices and systems for this specific use. These central issues will be described in the following section, but, overall, they are an important foundation before introducing the application of IoT within the context of a Smart city environment.

3.5.3.1: Security

The increasing growth in IoT has led to a number of intelligent objects and devices, which, in turn, are connected to the Internet as well as to each other. Smart home devices, Smart phones, wearable technology and tablets have been adopted into everyday life, and they are beginning to appear across a variety of functions and environments. An increasing quantity and variety of different devices are becoming connected to the Internet and through different forms of software. This can present several security challenges. Overall, this issue of security is considered to be a significant concern for many users and organisation. When implemented incorrectly, the lack of specific requirements for IoT security can lead to serious consequences in many areas. Moreover, such concerns are not only related to the possible mishandling of sensitive information, but also to the lives and health of the user to which these devices are connected (Organisation for Economic Co-operation and Development, 2016; Cisco and Forrester Research, 2015).

As mentioned in the previous section, this issue further indicates that, while the requisite development in components to realise the IoT is in place, the priority of security among many organisations may indicate the need for more standardised security procedures, readily applicable irrespective of the target platform. This should enable a given organisation or provider to benefit from IoT connectivity while maintaining the same security standards.

3.5.3.2: Privacy

In addition to the issue of security, the issue of privacy has also become an increasing concern. IoT devices are now able to collect significant volumes of data. Such data types include data on the user, such as name; age; gender; and most significantly, their real-time location. IoT devices deliver sensitive and personal information that can, in some cases, be unprotected or misused (Malina et al., 2016).

Additionally, instead of being restricted to the user’s device, this data is stored remotely in the Cloud, and thus is available on the Internet and liable to be exploited in instances where security measures break down. As well as this vulnerability, as data is gathered from multiple sensor sources, user data is, therefore, vulnerable to compromising the user’s confidentiality, and subsequently creating privacy challenges (Weber, 2015).

Again, similarly to the concern of security among organisations, the issue of privacy may represent for an organisation legal as well as procedural risks in safeguarding its employees. This implies that, although a given organisation may have confidence in the benefits of a specific IoT-oriented platform in spite of the risk to its privacy, its obligation to ensure data privacy for all its stakeholders may lead it to avoid adopting an IoT-based system.

3.5.3.3: Interoperability

As well as the issue of privacy and security, the ability to integrate two or more components, applications or systems to exchange data or share information in turn, creates many challenges when deploying IoT (Ganzha et al., 2017). Furthermore, the lack of interoperability constrains the adoption of IoT (Fortino et al., 2017), and adopting the term IoT for the same standard of devices will become increasingly difficult (Davies, 2015).

In addition, this issue could also be argued to be driven not by the capacity of the individual devices required for an IoT-based system; but by the lack of compatibility between competing providers. Allowing this competitive market to raise the standard of such devices individually still undermines the cross-platform integration that IoT demands at the macro level (Ganzha et al., 2017).

3.5.3.4: Big Data

In addition to the challenges to IoT mentioned above, there is also the fact that billions of devices generate large quantities of data in the form of sensor readings and notified actions to be taken. As a consequence, this vast amount of data creates significant challenges to businesses, as they need to be analysed and investigated, to ensure that the previously mentioned issues do not arise (Lee & Lee, 2015). Furthermore, this issue of data volume could be linked back to the previous issues of data privacy and security, whereby the data monitoring procedures and systems of organisations may not be able to expand rapidly enough in response to this increasingly large amount of data to analyse.

3.6: Smart City

3.6.1: Origin and Definition

As a concept, the notion of the Smart city can be traced back to 1990, when the California Institute for Smart Communities planned to use Information and

Communication Technology (ICT) to build Smart communities and cities (Albino et al., 2015).

In Figure 3.6, a brief history of Smart cities is presented. However, as this concept has developed over the following decades, researchers and companies have defined a Smart city according to the following different definitions:

The first definition is that of a city that '*monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens*' (Hall, 2000).

From one standpoint, this approach to the Smart city concept could be considered to be infrastructure focused, irrespective of the technology used to implement it. However, other definitions, while not placing the same emphasis on integrating physical public assets, consider integration of Smart communication protocols to be the key for this concept to work effectively.

In-line with this alternative focus, Cisco outlined the concept of the Smart city as comprising '*scalable solutions that take advantage of information and communications technology to increase efficiency, reduce costs and enhance the quality of life*' (Cisco, 2012). In contrast to the previous definition of Hall (2000), the increasing use of communication protocols already implemented within the current infrastructure, over a decade later, may also have influenced this shift from the simple integration of traditional public assets, to the focus on enhanced communication protocols to generate data and optimise the use of the assets themselves.

Similarly, the definition of the Smart city according to IBM is '*one that makes optimal use of all the interconnected information available today in order to better understand and control its operations and optimise the use of limited resources*' (Kehoe et al., 2011). Further to the previous point, this later definition of the Smart city, from a similar period, could indicate a shift towards leveraging Smart communication devices for enhanced efficiency and optimisation of the resources already present. Figure 3.6 outlines a brief history of Smart cities.

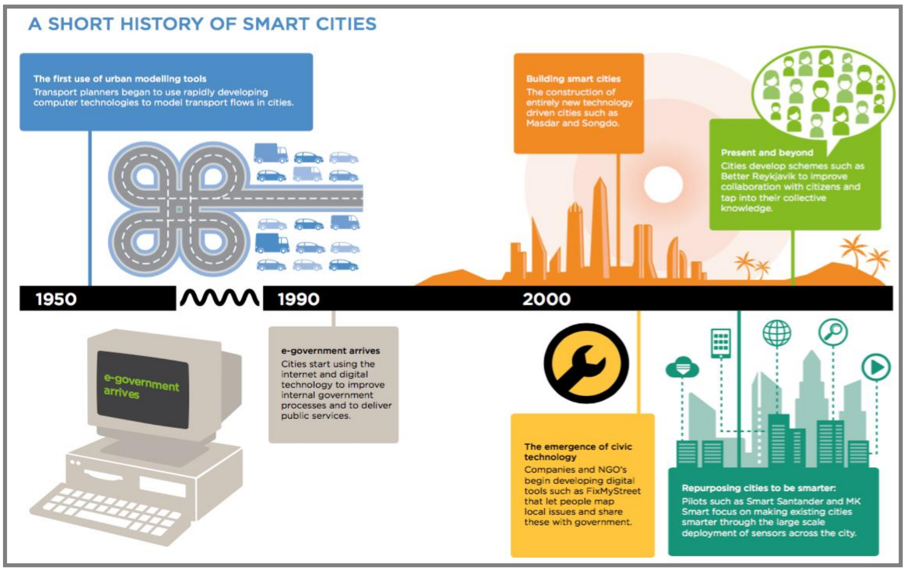


Figure 3.6: A Short History of Smart Cities
Source: (Saunders & Baeck, 2015)

3.6.2: Smart City Technologies

In 2014, Navigant Research reported that the market value of Smart cities was worth US $8.8 billion. The UK Department for Business Innovation and Skills (BIS) predicts that the global market for Smart city technologies and services is projected to be $408 billion by the year 2020 (Saunders & Baeck, 2015). Additionally, (ISO/IEC, 2014) reported that the adoption of the idea of Smart cities would require strong and robust technologies to assist in achieving the following:

- To ensure that the understanding of the primary concepts driving the Smart city model is shared, and that it can improve system interoperability through the development of coherent models
- To facilitate instrumentation through the use of multiple device types, responsible for the functions of: storing, capturing, and exploiting data generated from multiple forms of sources that are not only fixed, but also mobile
- To make the exchange of data rapid and fluid between different network topologies, and to use different forms of transmission and communication
- To aggregate data from systems and services that would not usually be used to generate such data
- To allow for the presentation of data in a variety of different formats, which is able to change according to the context and the technical system or person requiring it. This would allow the data to be accessed, visualised, and actioned more efficiently, thus increasing the data’s utility

- To allow the inter-cooperation of heterogeneous ICT-systems
- To ensure the safe and secure exchange of data
- To allow for an increased level of automation, enabling the functions within the city to function more effectively and reliably, thereby reducing the need for human input, except in cases where absolutely necessary.

Furthermore, the areas or components of a Smart city can encompass functions such as Smart environment, Smart energy, Smart security, Smart health, Smart administration, Smart office environment and residential buildings, Smart transportation, Smart industries (Gaur et al., 2015; Dubbeldeman & Ward, 2015), Smart safety, Smart water, Smart mobility, Smart waste, Smart education, Smart finance, Smart tourism, Smart retail, Smart logistics and Smart construction (Dubbeldeman & Ward, 2015).

3.6.3: Issues Related to the Smart City

However, in-spite of these promising advantages, critical issues can arise when the concept of a Smart city is adopted. Some of the issues are as follow:

- Security, safety and privacy of data are major concerns for a Smart city (Elmaghraby & Losavio, 2014)
- The ecological, political, social, economic and cultural challenges facing the adoption of a Smart city (Senate Department for Urban Development and the Environment, 2015)
- Integrative services are considered a challenge that faces governments (Nam & Pardo, 2011; Glasmeier & Christopherson, 2015)
- A labour market will be a challenge, as new skilled technological jobs will change the roles of old jobs (Dubbeldeman & Ward, 2015)
- The amount of data that is collected when deploying the idea of a Smart city is a challenge (Hashem et al., 2016)
- Management, technology and sustainability are other issues that can hinder the adoption of a Smart city(Joshi et al., 2016).

3.6.4: AAL and Smart Cities

When considering the different innovations that would be used to realise the Smart city concept, it is clear that the use of Ambient Assisted Living might offer a superior quality of life to elderly and disabled inhabitants with constrained mobility. Additionally, AAL can also be used in healthcare, to provide elderly and disabled inhabitants with tele-care, tele-rehabilitation and tele-medicine (Senate Department for Urban Development and the Environment, 2015). Furthermore, returning to the focus of more recent definitions of resource optimisation and efficiency, the ability to administer healthcare and support within the home may present an opportunity for reducing the consumption of resources that would otherwise be used up in travel and administrative activities used to facilitate the same functions within the public infrastructure today.

3.7: Conclusion

The increase in the number of people in the ageing population brings many challenges to the government and puts pressure on them. The progress in technologies can help governments to overcome the problems of an ageing population. AAL is advocated to provide elderly people with a better quality of life, and to allow them to live longer, more safely, more securely and in a more connected way, performing their daily activities. Smart homes, assistive robotics, mobile and wearable sensors and e-textiles are types of AAL technologies from which elderly people can benefit. The benefits are: independent living, assisting with daily activities, improving health, and being connected socially.

Although both communication protocols and Smart device technology have made significant advances in the two decades since the original concept of the Smart city was outlined, there are clearly several barriers to the realisation of the IoT and Smart city concepts that need to be overcome. From the micro-level of implementing an IoT system, to the macro level of the Smart city, the interoperability of otherwise capable existing devices is by far one of the most significant barriers to achieving a multi-platform collaborative environment, improving the innovative but as yet non-integrated nature of today’s Smart devices. Overall, while the innovation driven by this competition between different platform alternatives has enabled such devices to become increasingly efficient on an individual level, the lack of integration between devices, which is needed collectively for true IoT to be achieved, is a barrier that further implementations will need to address.

The next chapter includes the initial development of a decision making holistic framework for using AAL to support stakeholders by identifying the factors that affect the adoption of AAL technologies by conducting a literature review.

Chapter 4: Development of a Decision Making Holistic Framework for Using AAL to Support Stakeholders

4.1: Introduction

In Chapter 3, we discussed the definition of Ambient Assisted Living (AAL) and its technologies. Four technologies were reviewed, which are Smart homes, assistive robotics, wearable and mobile devices, and e-Textiles. Additionally, IoT and Smart cities were also discussed and reviewed. The challenges of IoT and Smart cities were clarified.

In this chapter, six theoretical frameworks/models are outlined. They are: the Unified Theory of Acceptance and Use of Technology, Technology Acceptance Model, Diffusion of Innovations Model, Technology-Organization-Environment framework, formation System Strategy (IS Triangle) and Human, Organization and Technology-fit factors. A theoretical framework is developed, based on a combination of IS trainable and Hot-fit frameworks, in order to form the foundation for this study.

Implementing AAL technologies requires investigating the challenge factors that affect the deployment and adoption of AAL. Therefore, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Liberati et al., 2009) method to identify the factors from a literature review. A thematic analysis was used, in order to analyse the data, and 35 articles were selected from different databases, to be reviewed and analysed. The results of analysing the literature review indicated that the factors could be categorised into four themes: human, technology, organisation and business, while the final list of factors includes 20 factors.

4.2: Review of Related Theoretical Frameworks/Models

AAL promises to promote independent living amongst elderly people (Billis et al., 2015). To the best of our knowledge, AAL technology, which is an Information and Communication Technologies (ICT) initiative (Monekosso et al., 2015; AALIANCE2, 2014), is a new technology in the KSA, and its adoption is an important initiative to support elderly people in developing countries and in the KSA in particular (Almalki & Williams, 2012). At present, AAL technology is still unexplored in the KSA, and there is a need to investigate the factors that affect its adoption by the KSA's elderly people and healthcare providers. The growing interest in deploying AAL technology can increase its high level of adoption (Grady et al., 2010).

Many theories have been used in Information System research to classify the core factors that affect deployment and adoption of ICT, including the Unified Theory of Acceptance and Use of Technology (UTAUT), Technology Acceptance Model (TAM), Diffusion of Innovations (DOI), Technology-Organization- Environment framework (TOE), Information System Strategy Triangle and Human, Organization and Technology-fit factors (HOT-fit).

4.2.1: The Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT) proposes four concepts, which act as factors for behavioural intentions and usage behaviour. These are: performance expectancy, effort expectancy, social influence, and facilitating conditions that influence behavioural intention to use a technology. The user acceptance can be directed by these factors, which can be moderated by variables: gender, age, experience, and the voluntary nature of use (Venkatesh et al., 2003).

4.2.2: Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) was proposed by Davis in 1989 and assumes that acceptance by the user is the critical factor for success of new information systems. It states that decisions to use a new technology can be affected by many factors, depending on the perceived ease of use and perceived usefulness. Davis defined perceived usefulness as an indicator of the extent of the enhancement of job performance, perceived by an individual who employs the new technology. Perceived ease of use can measure the degree to which the individuals suppose that the new technology would be used, exclusive of effort. TAM proposes that behavioural intentions to use an IT are specified by attitude and usefulness beliefs. Attitude is a result of usefulness and ease of use beliefs.

4.2.3: Diffusion of Innovations (DOI) Model

Rogers introduced the Diffusion of Innovations (DOI) Model in 1995. DOI clarifies how a population defines innovations. An innovation can be an object, idea, or behaviour that is perceived as new by its audience. Subsequently, the innovation attributes will be perceived, which will define its rate of adoption, in relation to the adopters' characteristics. DOI identifies five characteristics:

- Relative advantage refers to innovations that have an impact on behaviour, which would be changed if they show more sophisticated results than the old choices
- Compatibility focuses on integrating with the existing solutions, and meeting the users' needs
- Complexity states that innovations should be comfortable and seamless to use, and be recognised
- Trialability maintains that innovations should be checked and tested
- Observability affirms that the results should be noticeable and observable

According to Rogers (1995), there are five different types of adopters:

- Innovators: the adoption procedure is started by a small number of creative, visionary innovators
- Early adopters: they increase when the paybacks become attractive and clear
- Early majority: they need robust evidence of benefits to adopt the new model
- Late majority: the fears of adopting a new model play an important role in the adoption
- Laggards: the risk of adopting a new model can restrict and limit them.

4.2.4: Technology-Organization- Environment Framework (TOE)

The TOE framework was introduced by Tornatzky and Fleischer (1990) in 1990. TOE classifies three aspects of organisations' context, which affect the process by which they decide to adopt a technological innovation. They are: technological context, organisational context and environmental context.

The technological context defines the internal and external technologies that relate to the organisation.

The organisational context describes the resources and characteristics of the organisation (e.g., its size, human resources).

The environmental context is the arena relating to how an organisation is surrounded by business, competitors, industry, suppliers, the community, the government, etc (Angeles, 2014; Oliveira & Martins, 2011).

4.2.5: Information System Strategy (IS Triangle)

The information system strategy triangle is a framework that indicates the effects of IS on business, and identifies the importance of IS in any organisation (Pollack, 2010). It focuses on the essential connections between decisions of business strategy, information systems, and organisational scheme (Pearlson & Saunders, 2013). Pearlson & Saunders (2013) indicated that it is very important to align these three concepts, and identified the importance of IS in an organisation. Business strategy can be a key to driving organisational strategy and IS strategy.

The business strategy includes goals, objectives and purposes, which can be achieved by actions. Strategy begins with defining a mission. A mission is '*a clear and compelling statement that unifies an organization's effort and describes what the firm is all about*'. A business strategy is a plan that assists a business to select its mission and the way to achieve it. The business goals and objectives can be defined by the organisation and its IS (Pearlson & Saunders, 2013).

The organisational strategy involves designing the organisation and choosing the options that lead to the definition and management of the work processes. It is a plan that aims to achieve the business goals by structures, plans, work processes, people and hiring practices. Therefore, organisational strategy should be complemented with business strategy (Pearlson & Saunders, 2013).

The information systems strategy is considered to be the organisation's plan that provides information services. IS can assist a firm to apply its business strategy and can identify its capabilities. IS strategy should be complemented with business strategy. For the business to run properly, business goals should be supported by IS (Pearlson & Saunders, 2013).

'*IS strategy can itself affect and is affected by changes in a firm's business and organizational strategies. Moreover, IS strategy always has consequences—intended or not—on business and organizational strategies*' (Pollack, 2010; Pearlson & Saunders, 2013).

4.2.6: Human, Organization and Technology-fit factors (HOT-fit)

The HOT-fit framework was introduced after conducting a critical analysis of the current results of Health Information Systems (HIS) and Information System (IS) evaluation findings and is based on responses extracted from two conference presentations at the beginning of the research.

The Hot-fit was developed based on the utilisation of the IS Success Model and IT-Organization Fit Model (Yusof et al., 2008). The HOT-Fit refers to three contexts and each context includes a variety of dimensions, which are used to measure the net benefits.

The technological context includes: system quality, information quality and service quality. System quality refers to system performance. Information quality refers to the production of information, such as reports and prescriptions. It can be measured by information completeness, availability, accuracy, reliability, legibility, relevance, consistency and timeliness. Service quality is related to the services that are provided by the technology provider (Yusof et al., 2008).

The organisational context includes structure and environment. It includes planning, strategy, management, control system, autonomy, hierarchy, politics, culture, type and size and communication. The analysis of the healthcare organisations' environment can be undertaken by considering the type of populations being served, government, politics, its financing source, inter-organisational relationships, competition, localisation, and communication (Yusof et al., 2008).

The HOT-fit framework considers the human context/factor to be an important factor for adopting IT applications (Lian et al., 2014). It includes System Use and User Satisfaction (Erlirianto et al., 2015). System Use refers to the person who intends to use the system, his/her use levels, knowledge, beliefs, expectations and acceptance, training or resistance. User satisfaction refers to the measurement of the success of the system. It can refer to the users' attitudes and to the perceived usefulness of adoption (Yusof et al., 2008).

4.3: The Theoretical Foundation of AAL Dimensions Framework

The stakeholders of AAL technologies can be classified into elderly people and informal caregivers (human), care providers (organisations) and policy makers (organisations) (AALIANCE2, 2014). Niknejad et al. (2016) indicated that the human and organisational dimensions are significant factors for implementing Information Systems. Therefore, the adoption of AAL technologies can be affected by humans and organisations (AALIANCE2, 2014). In addition, business (finance) and technology acceptance (Spasova & Iliev, 2014; Al-Shaqi et al., 2016) are considered to be key factors that enable the adoption of AAL (AALIANCE2, 2014; Flandorfer, 2012; Lê et al., 2012). The adoption of wearable devices, which is considered to be an AAL technology, is affected by technological and human factors (Buenaflor & Kim, 2013).

According to the literature on theories for the adoption of ICT in general, and of AAL technologies in particular, and considering the aforementioned stakeholders and adoption factors, this research combined a framework of HOT-fit and IS triangle. This combination helps an appropriate theoretical foundation to be built for better understanding of the determinant dimensions and factors of AAL adoption. The proposed framework appears to be more comprehensive, and it integrates more factors that are considered to be crucial when adopting a new technology. We assume that integrating users' factors in this developed framework will clarify how organisational dimensions and individual factors can contribute to the adoption of AAL. Therefore, this research will combine two theoretical frameworks to build the proposed framework. HOT-fit and IS triangle are selected to be the theoretical foundation that will be aligned with the final results of the literature review, to frame this research. Figure 4.1 presents the theoretical framework (BOTH). The BOTH framework focuses on four dimensions, which are: business, organisation, technology, and human. These dimensions are within the framework that was developed by researchers when conducting the literature review.

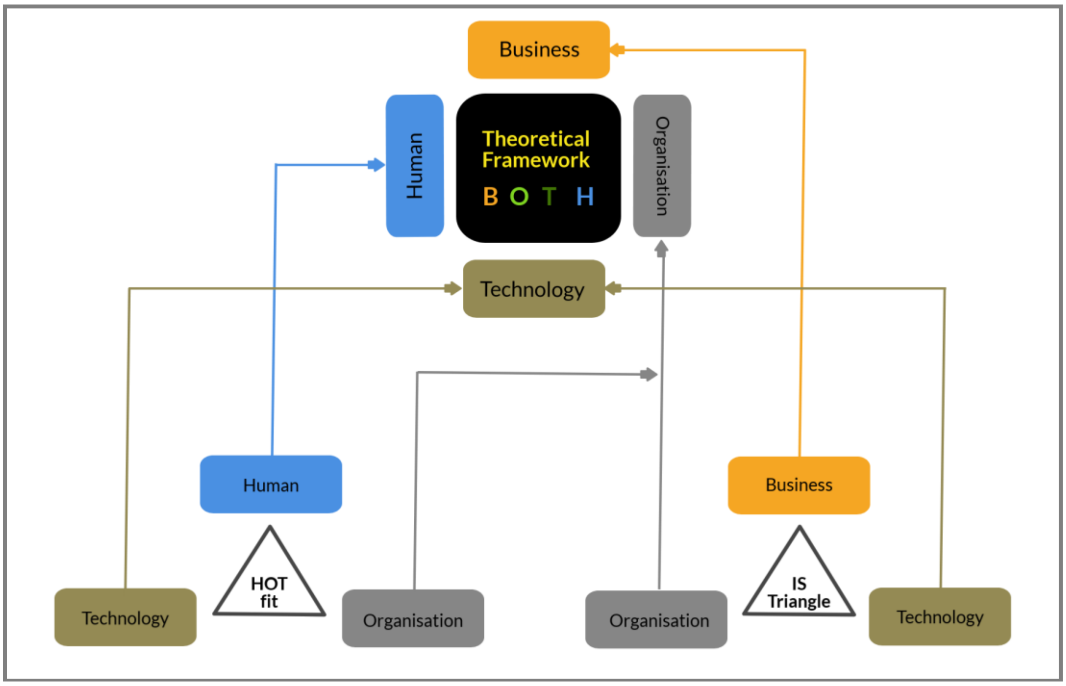


Figure 4.1: Theoretical Framework, Business, Organisation, Technology, and Human (BOTH)

4.4: Methodology of Developing the Dimensions and Factors Affecting the Adoption of AAL

The need for projects and applications of sensor devices has been increasing (Ylli et al., 2014). However, their adoption and deployment can be affected by many factors, and it is important to identify these factors in order to be the foundation for this research.

4.4.1: Method

A systematic literature review was conducted to identify the factors that affect the adoption of AAL technologies by elderly people. The research followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). It can be defined as '*an evolution of the original QUOROM guideline for systematic reviews and meta-analyses of evaluations of health care interventions*' (Liberati et al., 2009). The method identifies the criteria and processes for selecting the appropriate contents relevant to the ageing population, and the technology's adoption factors. It also determines the data analysis to identify and categorise these factors.

4.4.2: Search Strategy

Saudi Digital Library and Staffordshire University Library were used to retrieve articles from different databases (e.g., SCOPUS, IEEE Xplore, PubMed, ProQuest, Science Direct, ACM Digital Library, SpringerLink, Wiley Online Library). Google and Google Scholar were searched as well.

The keywords that were used were:

(((("ambient assisted living") OR ("smart home*") OR ("assistive robotic*") OR ("assistive robot*") OR ("wearable and mobile device*") OR ("e-textile*")) AND (("older people") OR ("senior people") OR ("elderly population") OR ("ageing population") OR ("aging population") OR ("population ageing") OR ("elderly person*") OR ("older person*") OR ("elderly people")) AND ((issue*) OR (barrier*) OR (factor*) OR (challenge*)))).

In addition, reports, working papers and websites were also searched and investigated. An Across-referencing method was used. Initially, a search for literature reviews was conducted, relating to the ageing population and the barriers for technology adoption in the KSA. However, to the best of our knowledge, there is limited research relating to this subject in the KSA. Therefore, the search was expanded to be worldwide.

4.4.3: Inclusion Criteria

The inclusion criteria that were applied for the selection articles were as follow:

- Disciplines should be Computer Science, Science and Social Science
- People should be 60 years and older, if the age is mentioned in studies
- Articles should be published in 2007 or later, because of the advancement in technology
- Systematic or any review, quantitative study, qualitative study or mixed method approach could be included
- The articles should be written in the English language because of the difficulties to translate the Arabic language to English
- Articles should be available online.

4.4.4: Study Selection

Refworks.proquest.com was used to identify duplicates articles, based on the title and the year of publication. The content of each selected article was checked by the researcher in conjunction with the principal supervisor, applying the inclusion criteria. If an agreement was not reached by the researcher and his supervisor, a third researcher could decide. Disagreements about any article were resolved by consensus. The results in searching these databases showed that there are 3,688 studies (3,607 from SDL and SUL and 81 from Google and Google Scholar). The deletion of different disciplines generated 869 studies. Deleting duplicates from SDL and SUL resulted in 818 unique articles. Screening the abstracts came out with 89 studies. The final accepted studies, after filtering the content, were 35 studies of which 34 were articles and 1 was a report. The flow chart for this process is presented in Figure 4.2. The outcome of this study resulted in 35 studies. The 35 eligible studies for this research are presented in Table 4.1.

The selected articles cover AAL technologies with the following frequencies:

- 16 articles discussed Ambient Assisted Living (AAL)
- 12 articles discussed Smart Homes (SHs)
- 3 articles discussed Assistive Robotics (AR)
- 3 articles discussed Wearable and Mobile Devices (WMD)
- 1 article discussed e-Textiles (e-T).

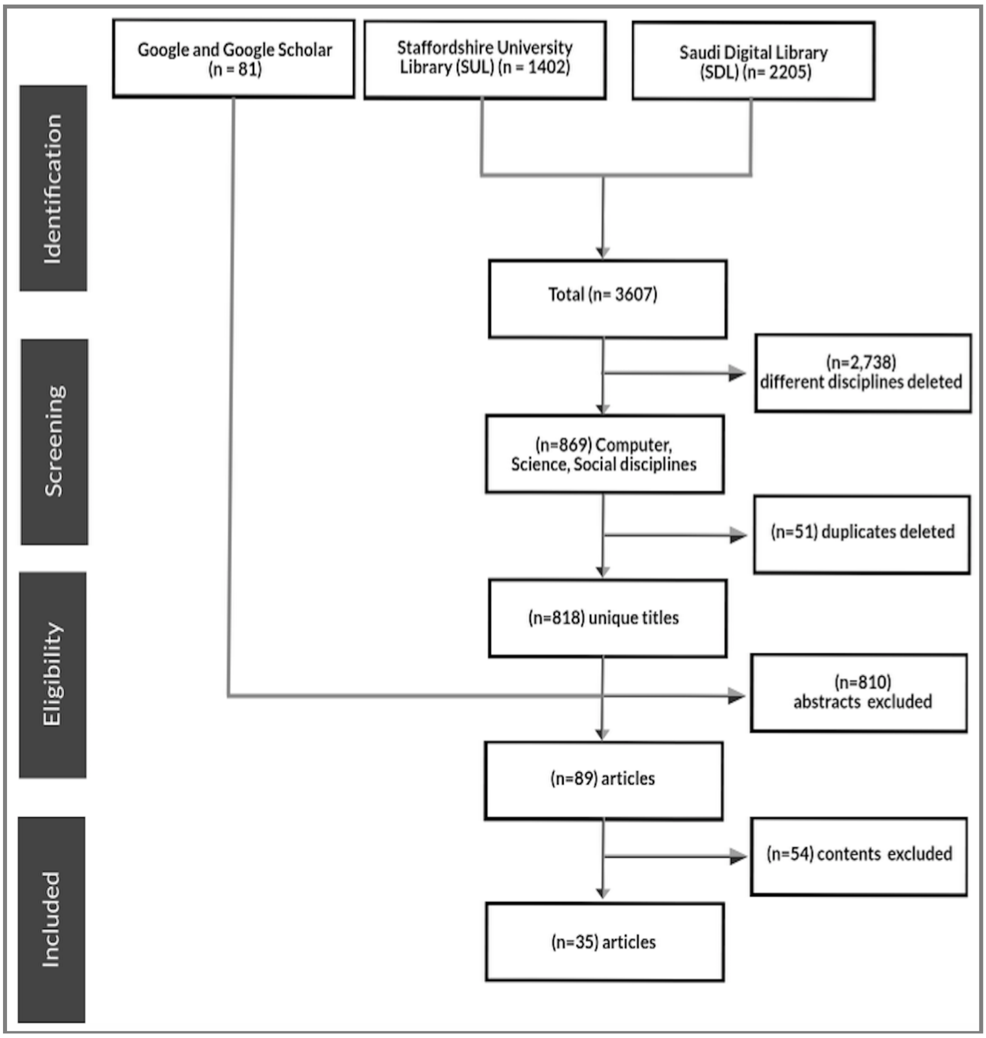


Figure 4.2: PRISMA Flowchart
Source: (Liberati et al., 2009)

Table 4.1: Classification of Articles by Domain

#	Authors and Years	Domains				
		AAL	**SH**	**AR**	**WMD**	**e-T**
1	(Coughlin et al., 2007)		✓			
2	(Kleinberger et al., 2007)	✓				
3	(Chan et al., 2008)		✓			
4	(Sun et al., 2009)	✓				
5	(Augusto et al., 2011)	✓				
6	(Ding et al., 2011)		✓			
7	(Pogorelc et al., 2012)	✓				
8	(Wu et al., 2012)			✓		
9	(Grgurić, 2012)	✓				
10	(Chan et al., 2012)				✓	
11	(Paoli et al., 2012)	✓				
12	(Flandorfer, 2012)			✓		
13	(Lê et al., 2012)		✓			
14	(Balta-Ozkan et al., 2013)		✓			
15	(Portet et al., 2013)		✓			
16	(Berglin, 2013)					✓
17	(Ayala & Amor, 2013)	✓				
18	(Khosla et al., 2013)			✓		
19	(Kim & Jeong, 2013)		✓			
20	(Parker et al., 2013)				✓	
21	(Rashidi & Mihailidis, 2013)	✓				
22	(Spitalewsky et al., 2013)	✓				
23	(AALIANCE2, 2014)	✓				
24	(Memon et al., 2014)	✓				
25	(Spasova & Iliev, 2014)	✓				
26	(Jaschinski & Allouch, 2015)	✓				
27	(Peruzzini & Germani, 2015)	✓				
28	(Dasios et al., 2015)	✓				
29	(Fletcher & Jensen, 2015)				✓	
30	(Ni et al., 2015a)		✓			
31	(Jacobsson et al., 2016)		✓			
32	(Al-Shaqi et al., 2016)	✓				
33	(Wilson et al., 2017)		✓			
34	(Alsinglawi et al., 2017)		✓			
35	(Majumder et al., 2017)		✓			

4.4.5: Data Analysis

Qualitative research consists of a variety of approaches, which aim to collect and analyse data in order to afford detailed explanations and interpretations about a phenomenon (Vaismoradi et al., 2016). Qualitative research discovers new subjects or issues, by making sense of the implications for persons involved (Hoe.J & Hoare.Z, 2013). It creates non-numerical data, using methods such as interviews, observations, semi-structured interviews, and focus group negotiations. Qualitative research is an interpretive perspective, which indicates that beliefs represent several realities, formed by individual opinions, contexts and meanings. In fact, the health research community has gradually adopted qualitative research in the past two decades (Tariq & Woodman, 2010).

Many studies indicated that there is a number of varied analytic methods used in qualitative research (Braun & Clarke, 2006; Vaismoradi et al., 2016). The analytic methods can include grounded theory, thematic analysis (Alhojailan, 2012), content analysis, (Vaismoradi et al., 2016; Williams, 2007) and narrative analysis (Akinsanya & Bach, 2014; Saunders et al., 2009).

Grounded theory was defined by (Creswell, 2003) as '*researcher attempts to derive a general, abstract theory of a process, action, or interaction grounded in the views of participants in a study*'. Williams (2007) argued that the theory should not be generated from a literature review. Therefore, grounded theory was not considered to be an appropriate analytic method for this study.

A narrative is considered to be a story, which includes a sequence of actions that occur throughout a period of time. '*It mostly follows a chronological order and usually contains a link to the present in the form of a lesson learnt by the narrator*'. Therefore, it aims to discover connections through investigating and assessing several parts of the narrative (Akinsanya & Bach, 2014). This study does not follow a chronological order; therefore, a narrative analysis was not considered to be an appropriate analytic method for this study.

Thematic analysis is a process that identifies analyses and reports themes that relate to data. It generates and explains data in significant detail (Alhojailan, 2012; Braun & Clarke, 2006). Content analysis is defined as '*a detailed and systematic examination of the contents of a particular body of materials for the purpose of identifying patterns, themes, or biases*' (Williams, 2007).

Thematic and Content analysis can be considered to be similar methods of analysis. Furthermore, both have been used to classify patterns throughout qualitative data. However, the themes of content analysis can be quantified, whereas the themes of thematic analysis cannot be (Braun & Clarke, 2006).

Alhojailan (2012) stated that thematic analysis is '*considered the most appropriate for any study that seeks to discover using interpretations. It provides a systematic element to data analysis. It allows the researcher to associate an analysis of the frequency of a theme with one of the whole content. This will confer accuracy and intricacy and enhance the research's whole meaning. Qualitative research requires understanding and collecting diverse aspects and data. Thematic Analysis gives an opportunity to understand the potential of any issue more widely*'.

In addition, Braun & Clarke (2006) indicated that thematic analysis can be considered to be a foundational method for qualitative analysis (Braun & Clarke, 2006). Therefore, thematic analysis was chosen as the analytical method for the data analysis for this study.

4.4.6: Thematic Analysis

The thematic analysis method was introduced by (Braun & Clarke, 2006). It is composed of three link streams: data reduction, data display, and data conclusion-drawing/verifying (Alhojailan, 2012). It is a process used to analyse qualitative research, and it involves six phases that lead to the achievement of the aims of the study. This research adopted these phases, which were developed by (Braun & Clarke, 2006), as illustrated in Table 4.2.

Table 4.2 Phases of Thematic Analysis

#	Phase	Description of the process Transcribing
Phase 1	Familiarising yourself with your data	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas. Coding.
Phase 2	Generating initial codes	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
Phase 3	Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme.
Phase 4	Reviewing themes	Checking in the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic „map" of the analysis.
Phase 5	Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells; generating clear definitions and names for each theme.
Phase 6	Producing the report	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Source: (Braun & Clarke, 2006)

4.4.7: The Results of Data Analysis

This section presents the findings from analysing the articles that have been selected through the literature review. This analysis follows the six phases that were developed by (Braun & Clarke, 2006) and discussed in the previous section.

The results of this analysis are as follow:

Phase 1: Familiarising yourself with your data

In order to be familiar and obtain a high level of understanding of the contents of the 35-selected articles, the researcher had to read them more than once. It was important to search for patterns or themes emerging from the articles and take some notes. Therefore, themes were recognised and initial ideas for coding were defined.

Phase 2: Generating initial codes

This phase involves producing initial data coding. The initial data coding was developed by the researcher and then was reviewed by the principal supervisor. The researcher developed the coding manually, by highlighting and writing down systematically as many candidate factors as possible. The coding was double checked for consistency. The data that were recognised to have the same code were grouped. Finally, the production of this phase resulted in a long list of codes, which were called factors.

Phase 3: Searching for themes

In this phase, a long list of different codes, which identified the factors, was determined. Since different terminology was used in the literature, this research adopted the term 'dimension' for what, in the literature, is often called 'theme', and similarly, 'factor' for 'sub-theme'. Then, the perceived factors were grouped into potential dimensions. The themes and sub-themes (dimensions and factors) were formed from the codes. The results of the search developed the thematic map as shown in Figure 4.3 and consisted of:

- Four perceived dimensions: Technology, Human, Organisation and Business
- Fifty-two perceived factors.

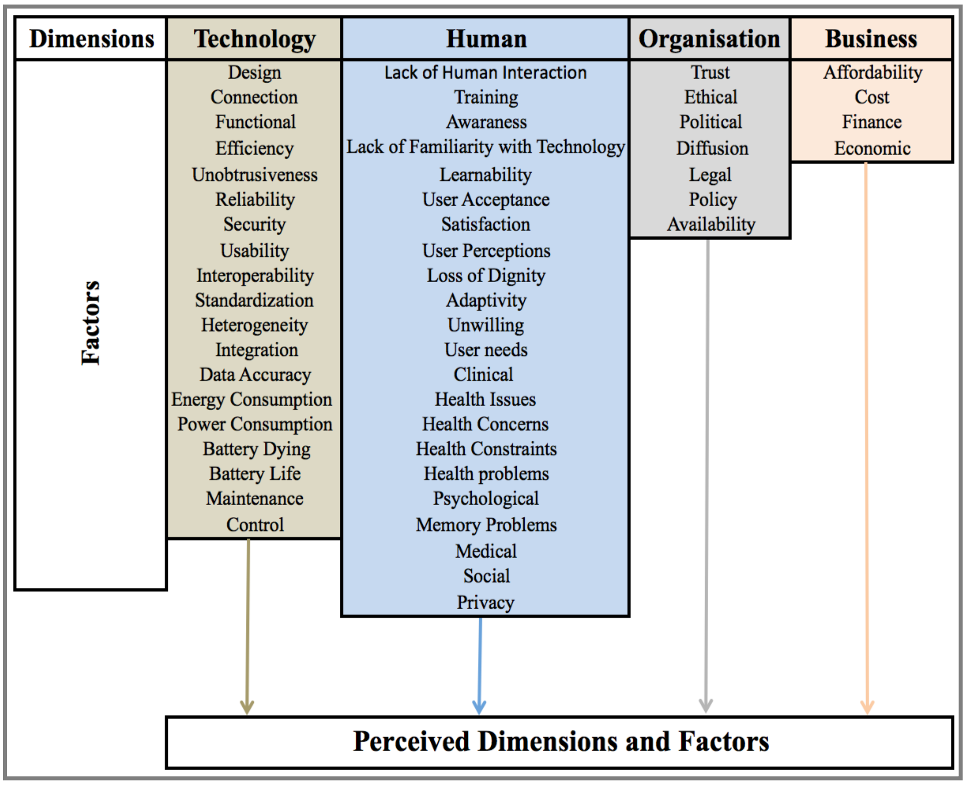


Figure 4.3: The Initial Map of Perceived Dimensions and Factors

Phase 4: Reviewing themes

The fourth phase consisted of two steps: reviewing and refining themes (Braun & Clarke, 2006). The perceived factors, that had been defined, were re-read, in order to make sure they related to the dimensions, and to guarantee that perceived factors formulated coherent patterns. Therefore, some factors were combined and refined as follows:

Technology:

- Design, connection, functional, efficiency, and unobtrusiveness were merged and renamed as design
- Heterogeneity, standardisation, interoperability, and integration were merged and renamed as interoperability
- Power consumption, battery dying, battery life, and energy consumption were merged and renamed as energy consumption
- Maintenance and control were merged and named maintenance.

Human:

- Satisfaction, acceptance, user perceptions, loss of dignity, adaptively, and unwilling were merged and renamed as user acceptance
- Clinical and user need were merged as user needs
- Health concerns, health constraints, health problems, physical, psychological, memory problems, and medical were merged and renamed as health issues
- Awareness, lack of familiarity with technology and learnability were merged and renamed as training.

Organisation:

- Trust, legal, political, diffusion, ethical, policy, and availability were kept as they were.

Business:

- Cost, economic, finance and affordability were kept as they were

The dimensions were kept as they were, and the results of merging and refining the factors (52 factors) were as follow, and as are presented in Figure 4.4.

Technology: design, reliability, security, usability, interoperability, data accuracy, energy consumption and maintenance.

Human: lack of human interaction, training, user acceptance, user needs, health issues, social, and privacy.

Organisation: trust, legal, political, diffusion, ethical, policy and availability

Business: cost, finance, economic and affordability.

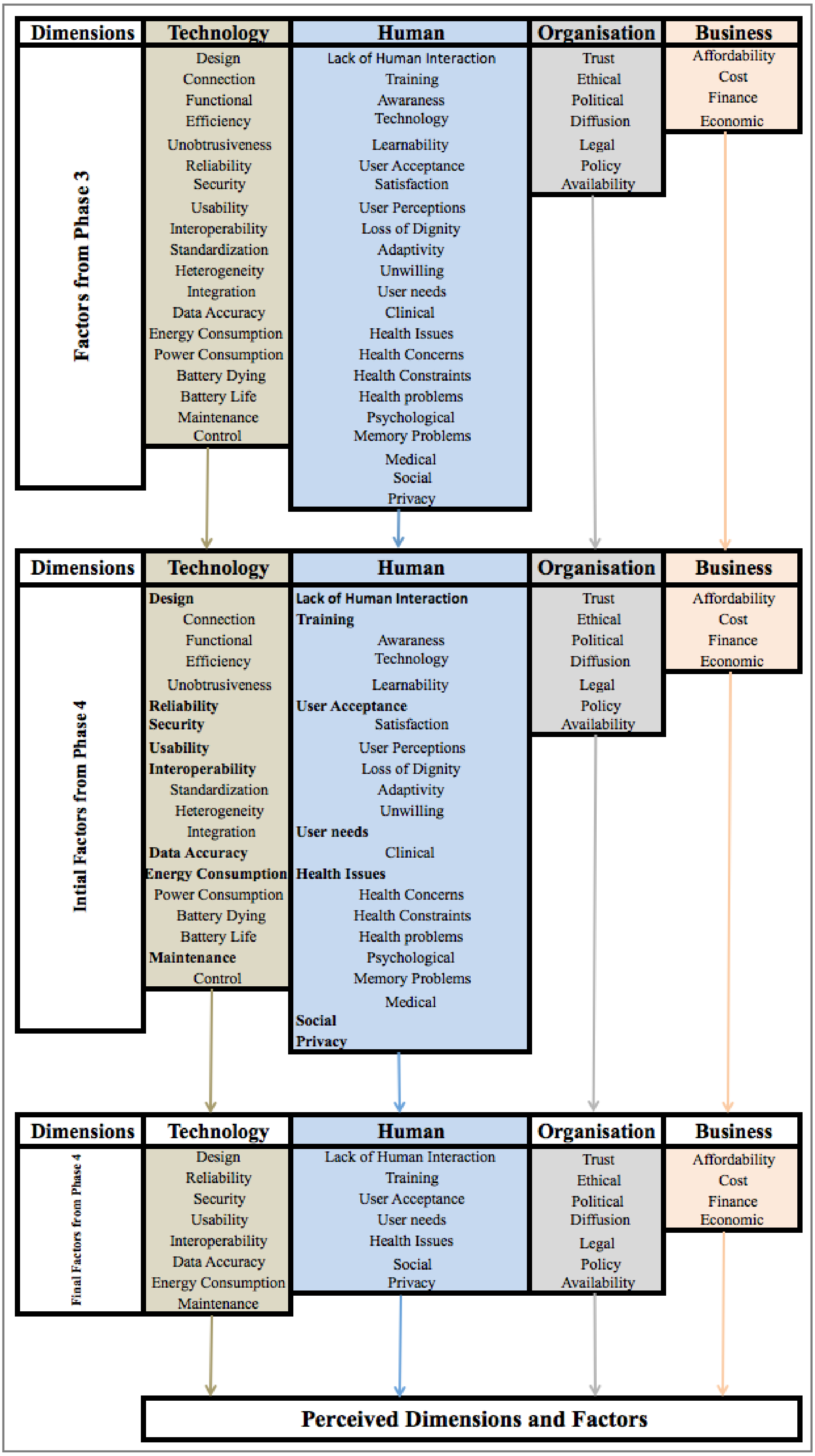


Figure 4.4: The List of Factors after Reviewing and Refining

Phase 5: Defining and naming themes

This phase involved re-analysing the perceived dimensions and their factors, in order to finalise the list of results. The perceived dimensions and their factors were discussed with the principal supervisor and IT specialists. As a result, the perceived dimensions were kept as mentioned, and the perceived factors were revised, based on the recommendations and suggestion received from the principal supervisor and IT specialists, as follow and as shown in Figure 4.5:

Organisation: legal, political, diffusion, ethical and policy are merged and renamed as processes.

Business: cost, finance and economic were merged and renamed as hard financial analysis, and affordability was renamed as soft financial analysis (Alharbi et al., 2016).

However, technology and human dimensions, and their factors, were kept as defined in phase four.

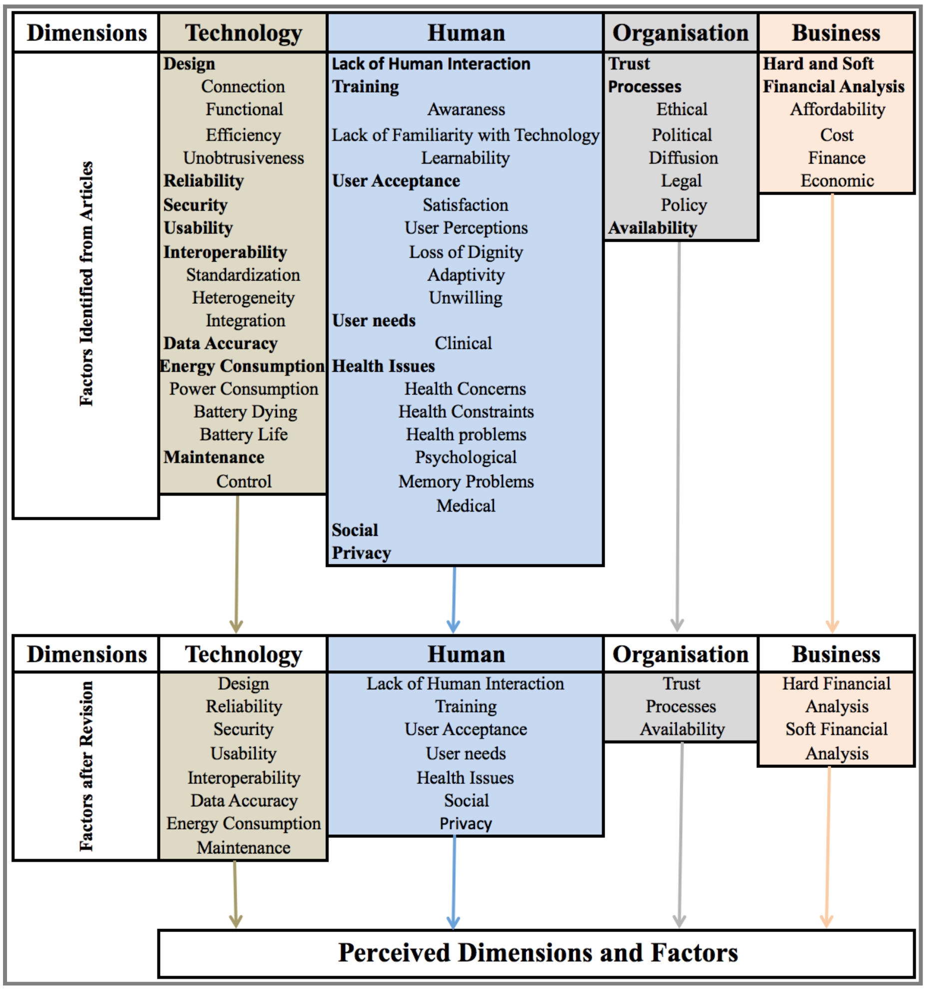


Figure 4.5: The Dimensions and Factors after Revision

The initial decision-making framework consisted of four dimensions and twenty factors. The final perceived dimensions and their revised perceived factors that were derived from the literature review are illustrated in Figure 4.6.

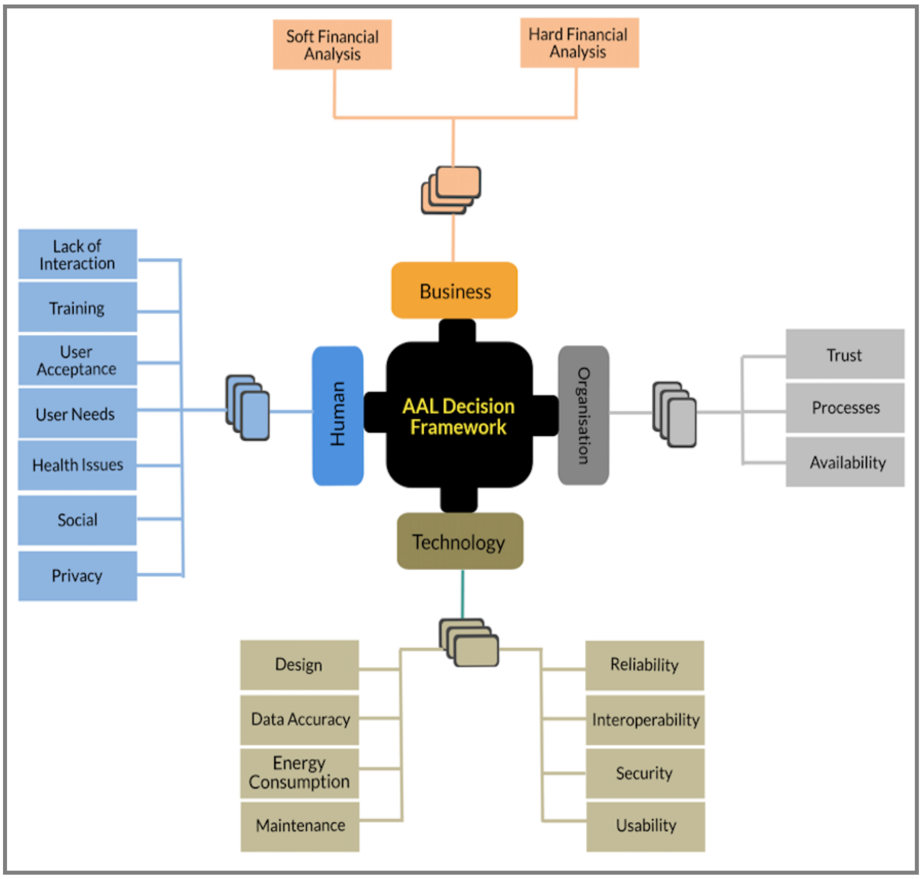


Figure 4.6: The Initial Decision-Making Framework to Adopt AAL

Phase 6: Producing the report

This phase presents the production of a report, according to the final results that were extracted from the previous phases. The report aimed to demonstrate concise, coherent, logical and non-repetitive themes; dimensions; sub-themes; and factors (Braun & Clarke, 2006). This report involved producing the following tables:

- The first table shows the final themes; dimensions, and sub-themes; factors, with theirs assigned codes, as in Table 4.3.

Table 4.3: The Dimensions and their Factors, with their Codes

Dimensions	Factors	Code
Technology	Design	T1
	Reliability	T2
	Security	T3
	Usability	T4
	Interoperability	T5
	Data Accuracy	T6
	Energy Consumption	T7
	Maintenance	T8
Human	Lack of Human Interaction	H1
	Training	H2
	User Acceptance	H3
	User needs	H4
	Health Issues	H5
	Social	H6
	Privacy	H7
Organisation	Trust	O1
	Processes	O2
	Availability	O3
Business	Hard Financial Analysis	B1
	Soft Financial Analysis	B2

- Table 4.4 presents the articles that discussed each factor and the percentage of each factor's appearance. It includes the final results of the report and the merging factors.

Table 4.4: Frequencies of Factors that are Discussed in Articles

#	Authors and Years	Codes of Identified Factors																			
		T1	T2	T3	T4	T5	T6	T7	T8	H1	H2	H3	H4	H5	H6	H7	O1	O2	O2	B1	B2
1	(Coughlin et al., 2007)	✓	✓		✓							✓				✓	✓	✓			✓
2	(Kleinberger et al., 2007)		✓	✓	✓	✓				✓		✓		✓	✓			✓			
3	(Chan et al., 2008)		✓			✓						✓	✓					✓		✓	
4	(Sun et al., 2009)													✓					✓		
5	(Augusto et al., 2011)			✓												✓					
6	(Ding et al., 2011)												✓					✓			
7	(Pogorelc et al., 2012)															✓					
8	(Wu et al., 2012)									✓					✓			✓			
9	(Grgurić, 2012)	✓	✓	✓	✓	✓					✓				✓	✓	✓		✓	✓	
10	(Chan et al., 2012)	✓	✓	✓		✓						✓						✓		✓	
11	(Paoli et al., 2012)					✓															
12	(Flandorfer, 2012)													✓	✓			✓		✓	
13	(Balta-Ozkan et al., 2013)		✓	✓		✓			✓							✓	✓			✓	
14	(Portet et al., 2013)				✓	✓			✓							✓					
15	(Berglin, 2013)	✓						✓	✓					✓				✓			
16	(Ayala & Amor, 2013)					✓					✓										
17	(Khosla et al., 2013)																			✓	
18	(Kim & Jeong, 2013)																			✓	
19	(Parker et al., 2013)	✓						✓		✓	✓	✓		✓		✓				✓	
20	(Rashidi & Mihailidis, 2013)	✓		✓											✓	✓		✓			
21	(Spitalewsky et al., 2013)					✓									✓	✓		✓		✓	
22	(AALIANCE2, 2014)			✓		✓									✓			✓		✓	
23	(Memon et al., 2014)		✓	✓	✓	✓	✓									✓				✓	
24	(Spasova & Iliev, 2014)	✓		✓				✓						✓				✓			
25	(Jaschinski & Allouch, 2015)	✓	✓		✓				✓	✓				✓	✓	✓	✓			✓	
26	(Peruzzini & Germani, 2015)					✓						✓									
27	(Li et al., 2015)											✓						✓			
28	(Dasios et al., 2015)			✓												✓					
29	(Fletcher & Jensen, 2015)	✓										✓									
30	(Ni et al., 2015)															✓					
31	(Jacobsson et al., 2016)			✓												✓					
32	(Al-Shaqi et al., 2016)	✓				✓		✓				✓			✓						
33	(Wilson et al., 2017)			✓												✓					✓
34	(Alsinglawi et al., 2017)																	✓		✓	
35	(Majumder et al., 2017)	✓	✓	✓			✓	✓								✓					
% of articles discussed factors		31%	26%	37%	17%	37%	6%	14%	11%	11%	9%	26%	6%	20%	26%	40%	11%	40%	6%	34%	6%

4.5: Conclusion

The advantages of AAL are now generally recognised, and the four major AAL technologies were considered in Chapter 3. However, these AAL technologies are still largely unknown in the KSA, and their acceptance and adoption present major challenges. Therefore, it is vitally important to develop a holistic framework that allows the adoption and implementation of AAL throughout the KSA, for the support of stakeholders. Six theoretical frameworks were carefully considered, and the PRISMA method was chosen to determine the factors affecting the adoption of AAL. A comprehensive literature review singled out 35 relevant articles/studies, and the Theoretical Framework was then chosen, based on a combination of IS Triangle and Hot-fit Framework, as the foundation of this study. The four Dimensions/Pillars of the framework are: Human, Technology, Business, and Organisation, as shown in Figure 4.1.

The chosen ‘Six Phase Thematic Data Analysis’ of the 35 articles selected from the literature review resulted in 52 perceived factors affecting the adoption of AAL. In Phases 1 and 2 these factors were assigned codes, and in Phase 3, these coded factors were allocated to the four Framework Dimensions, as shown in Figure 4.3. Phase 4 refined the analysis by combining some of the factors, as shown in Figure 4.5, and a final revision (Phase 5) led to the Framework shown in Figure 4.6.

A final Phase 6 produced the report, with the Dimensions, Factors and Codes shown in Table 4.3, and the ‘Frequencies of factors discussed in the articles’, as shown in Table 4.4.

The ‘Decision Making Framework for the Adoption of AAL’, shown in Figure 4.6, represents the framework recommended by this study for guiding and ensuring the adoption of AAL throughout the KSA.

In the next chapter, the two primary research methods, a questionnaire for elderly people and a Community of Practice (CoP) with the healthcare provider that were conducted, are discussed and analysed.

Chapter 5: Primary Research: Questionnaire and CoP

5.1: Introduction

In the previous chapter, we discussed the development of a proposed framework, using AAL technologies, for overcoming the problems arising from the ageing population in the KSA. This chapter discusses a survey that was conducted in the KSA, on the adoption of Ambient Assisted Living technologies. The aim of this study is to extract the attitudes and perceptions of elderly people, regarding the level of acceptance for the use of AAL technologies, and to identify the factors that affect the adoption of AAL technologies in the KSA. Ambient Assisted Living (AAL) promises to play a prominent role in providing independence and quality of life for elderly people.

Despite the benefits that are delivered by AAL, there are some factors that affect its adoption. Four themes were identified as dimensions that affect the adoption of AAL technologies, as indicated in the previous chapter. One of the significant factors is the 'acceptance' factor (Jia et al., 2015; Biljon & Renaud, 2009; Care Innovations, 2013). Therefore, a quantitative approach was used, and a questionnaire method was implemented. Then, a qualitative approach was conducted using a Community of Practice (CoP) study. The data collected were analysed, discussed and presented in this chapter. The refinement of the AAL decision framework that was developed in Chapter 4 is presented based on the results of the questionnaire and the CoP.

5.2: Questionnaire

A questionnaire is '*a group or sequence of questions designed to obtain information on a subject from a respondent*'. Questionnaires can have a major effect on the quality of data because they play a critical role in the collection of data process. The questions that are chosen should achieve the objective of the research and deliver data that lead to significant data analysis (Statistics Canada, 2010).

5.2.1: Questionnaire Design

A well-developed questionnaire:

- Should gather significant data including only a minimum number of inconsistencies and mistakes

- Should be respondent-friendly
- Should be cost-efficient and timely (Statistics Canada, 2010)
- Should comply with ethical standards.

The purpose of the questionnaire is to extract the attitudes and perceptions of elderly people regarding the level of acceptance of the use of AAL technologies, and to identify the factors that affect the adoption of AAL technologies in the KSA.

5.2.2: Instruments

A questionnaire is an instrument that is used to collect data from participants. It consists of a variety of questions for collecting data (Saunders et al., 2009). The questionnaire was available in the English and Arabic languages. It included an overview of the research project, and it provided information and guidance to encompass ethical matters, such as the ability to withdraw from the survey at any time. It also allowed a member of the family to assist an elderly person to fill-in the survey (Appendix 2).

5.2.3: Content of the Questionnaire

Questions can be divided into two types: open questions and closed questions. Closed questions can include: two-choice questions, multiple choice and checklist questions, ranking questions or rating questions (Statistics Canada, 2010).

In this research, the questions are selected, based on the literature review, in order to meet the aims and objectives of the research. The questionnaire was designed using four types of questions. Firstly, there were eight multiple-choice questions, using a Likert scale measurement. The Likert scale consisted of a 5-point scale (strongly agree= 5 to strongly disagree =1). Some researchers have used 7- and 9-point scales that include extra granularity. However, others have used 4-point scales, to force the selection, but the most usually observed is a 5-point scale (Bertram, 2007). Secondly, there were two open-ended questions. Thirdly, the questionnaire included six Yes/No questions, and finally, it asked eight multiple-option questions. It was expected that the questionnaire would take approximately 20 minutes to complete. The questionnaire was divided into six main sections:

- Demographics of Participants
- Social Interaction of Participants
- Home, Concerns and Factors of Participants
- AAL Technologies

- Professional Carers
- Open-ended Questions.

5.2.4: Piloting the Questionnaires

It is important to test a survey questionnaire before publishing it. Pilot testing is an effective method that evaluates a survey, in order to determine the time taken, to understand the instructions of the questionnaire, to identify questions that do not make sense to participants, to check language errors, and any other problems. It is also important to test the questionnaire on a small sample of colleagues working in the same area (Burgess, 2001). Therefore, five groups were involved in the pilot testing for this study:

- Some colleagues working in the same area
- The Ministry of Labour and Social Development
- English and Arabic language specialists
- Two elderly people aged 62 years and 68 years
- Supervision team

The pilot testing resulted in wording errors being found, but there was no need for clarification of instructions; no unclear questions were found and there was no need to change the type of questions. Thus, the researchers made the required amendments.

5.2.5: Administration of the Questionnaire

The questionnaire was delivered to participants via an online method, using Qualtrics.com, emails, Instant Messages (WhatsApp) and social media (Twitter and Linkedin). A Snowball technique was used to conduct this questionnaire. Snowballing is a technique that asks participants to pass the questionnaire on to other potential respondents (Voicu & Babonea, 2007). In order to show the credibility and authority of the questionnaire, the logo of Staffordshire University and Shaqra University were added to it.

5.2.6: Data Collection

Data collection can be defined as '*the process of gathering the required information for each selected unit in the survey*'. Therefore, the method of data collection for this research is a computer-based method, which is: '*data collection and data capture are combined, resulting in an integrated, faster and more efficient collection and capture process*' (Statistics Canada, 2010).

The total number of respondents for the survey was 420, and of these 194 responses were fully completed. The acceptance rate of the survey was 46.2%, because the analysis was based on the 194 fully completed surveys. Therefore, 226 participants were excluded because they returned incomplete questionnaire, missing answers to some questions. This sample size was almost double the accepted level that is recommended by Kline (1979) and Gorsuch (1983) (MacCallum et al., 1999). In addition, Burgess (2001) indicated that it is common that a completed questionnaire response rate can be only 20% of all the responses.

5.2.7: Reliability of the Questionnaire

Cronbach's alpha measures the reliability of the questionnaire. We conducted a Cronbach's alpha test, and the results are shown in Table 5.1. The alpha value for the entire questionnaire was 0.729; this means that the formulated questionnaire was acceptable (Tavakol & Dennick, 2011). This is a good value since it is high enough to demonstrate that the questionnaire was reliable.

Table 5.1: Cronbach's Alpha

Reliability Statistics	
Cronbach's Alpha	N of Items
0.729	61

5.2.8: Statistical Tests

A Kolmogrov-Smirnov test is used to test the distribution of data. This is to evaluate if the data are normally distributed or not. Based on the results of this test, we can decide which tests are appropriate for measuring and quantifying the data (Amr et al., 2014). If the result of the Kolmogrov-Smirnov test is below .05, this means that the data are not normally distributed. This violates the parametric assumptions, making non-parametric tests more appropriate for measuring the data. According to the results of the test, the Asymp Sig value for all data is 0.001. This shows that the data are not normally distributed.

5.2.9: Data Analysis

Data analysis involves '*summarising the data and interpreting their meaning in a way that provides clear answers to questions that initiated the survey. It consists of interpreting tables and various summary measures, such as frequency distributions, means and ranges, or more sophisticated analyses may be performed*'. The analysis can be presented in many formats, such as charts, diagrams and tables, etc (Statistics

Canada, 2010). In this research, we used pie charts and columns charts.

Therefore, this section provides the frequencies and descriptive statistics related to the demographics of participants who completed the questionnaire. All of the ‘positive’ responses were added together, meaning the ‘strongly agree’ values were added to the ‘agree’ values. Similarly, the ‘negative’ responses were combined so that strongly negative and negative were reported as one value.

Quantitative data was analysed through descriptive statistics in the form of frequencies and percentages, using the computer-aided software Statistical Package for Social Sciences (SPSS) version 20 and Piktochart Software.

5.2.9.1: Demographic of the participants:

The total number of responses was 194 out of 420. According to the descriptive analysis, male respondents were in the majority (63.9%), while 36.1% of participants were female. The age group 60–69 years old made up 72.2% of respondents, the age group 70–79 made up 18.6%, and 9.3% of respondents were above 80 years old. This indicates that the age group between the ages of 60–69 contained the largest group of participants in the study. 94.3% of the participants were Saudi, while 5.7% of the participants were non-Saudi. Most of the participants lived with their family members (82.5%), while 8.8% of them lived alone as in Figure 5.1 (see Table 5.2).

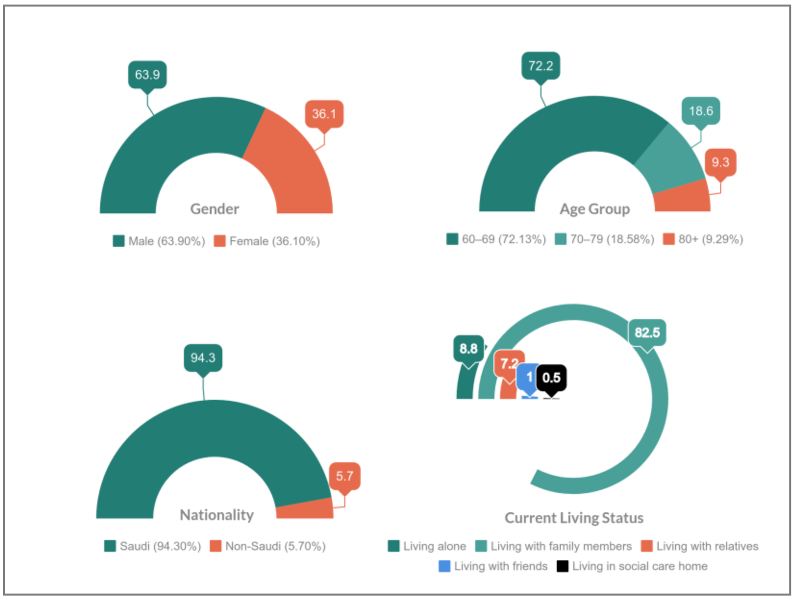


Figure 5.1: Demographics of Participants (n=194)

Table 5.2: Demographics of Participants (n=194)

Variables		Frequency	Percentage
Gender	Male	124	63.9
	Female	70	36.1
Age Group	60–69	140	72.2
	70–79	36	18.6
	80+	18	9.3
Nationality	Saudi	183	94.3
	Non-Saudi	11	5.7
Current living status	Living alone	17	8.8
	Living with family members	160	82.5
	Living with relatives	14	7.2
	Living with friends	2	1
	Living in social care home	1	0.5

5.2.9.2: Social Interaction:

Social Network: 89.2% of participants showed that they used social networks to connect with their families, relatives and friends. SMS (44.8%) was the most common communication social network used by elderly people. Twitter came second with 16.1% and Facebook (14%) was reported as the third tool. 10.8% of participants indicated that they do not use any social networks to communicate, as illustrated in Figure 5.2

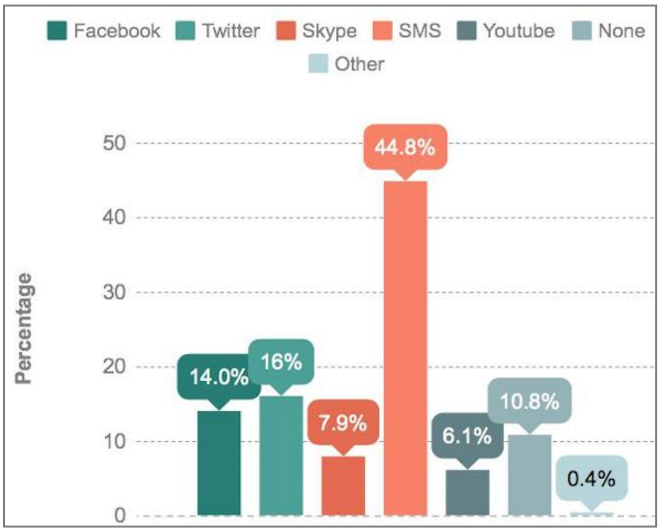


Figure 5.2: Social Network

5.2.9.3: Home, Concerns and Factors

Home Equipment: 90% of participants' homes were equipped with the Internet, 9% with camera surveillance and 7% with a camera with video recording capability, as indicated in Figure 5.3.

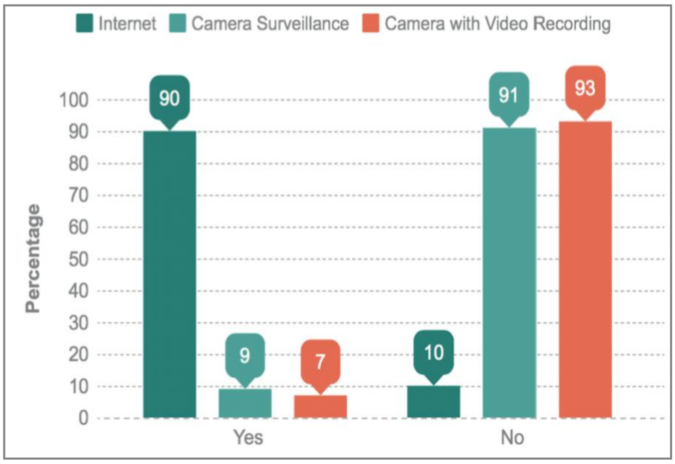


Figure 5.3: Home Equipment

Sensors Preferences: most participants, 62.2%, favoured using a temperature sensor and bed sensor (58.8%) was the second preference. The motion sensor was the third preferred sensor with 51% as shown in Figure 5.4.

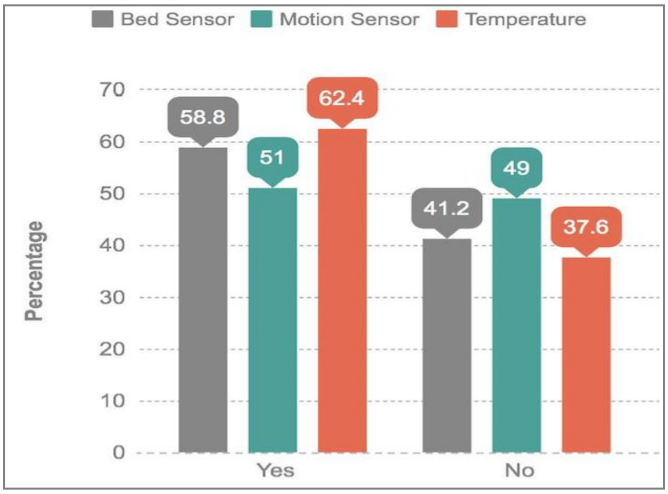


Figure 5.4: Sensors Preferences

Participants' Concerns: individual privacy and personal health status were considered the primary concerns affecting the adoption of AAL technologies (53%). Furthermore, 52% of participants were concerned about personal data, compared with 21% who were not concerned about it. Overall, participants had concerns (52.75%) about privacy, personal health and personal data (see Figure 5.5).

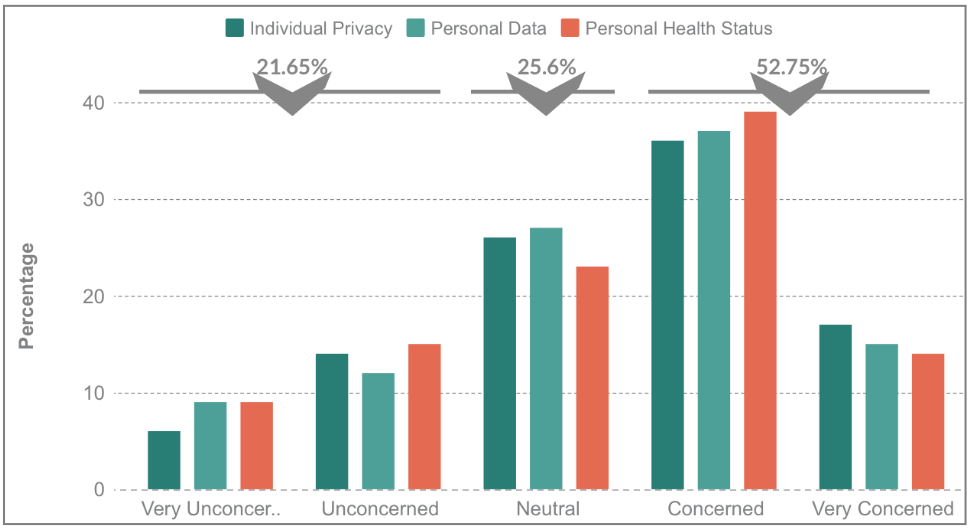


Figure 5.5: Participants' Concerns

Factors hindering the adoption of AAL technologies: the results showed that there are some factors that hinder the adoption of AAL technologies (see Figure 5.6). Home safety was the most-reported factor that affects the adoption of AAL technologies (87%), while home security was not far behind, with 85% of respondents reporting it as a factor. Usability of technology, size intrusion, and weight intrusion of technological devices were other factors reported, with 65%, 57% and 57%, respectively. Overall, 70% of participants indicated that these factors affect their adoption.

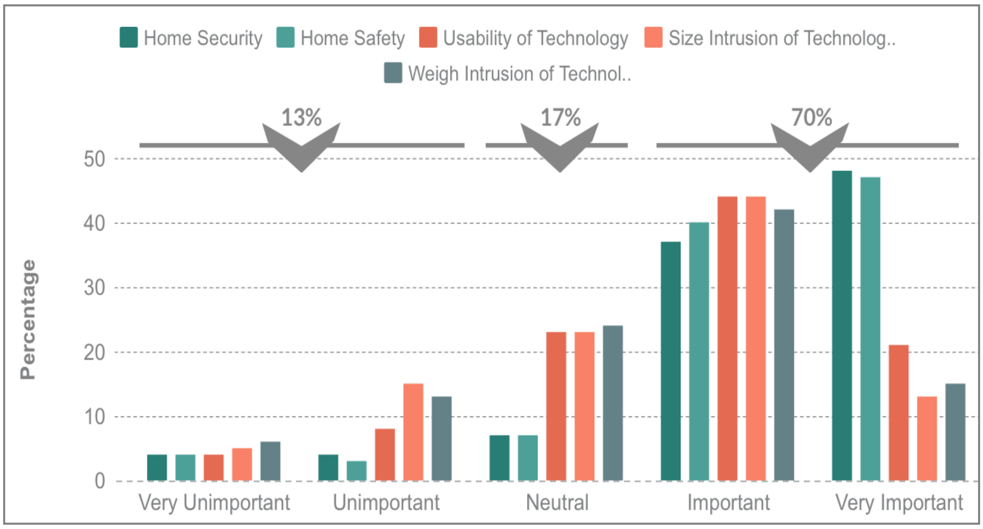


Figure 5.6: Factors Hindering the Adoption of AAL Technologies

5.2.9.4: AAL Technologies

Preferences of technology usage: the findings indicated that the majority of the elderly intend to use AAL technologies. The findings revealed that 46% of participants use Smart Devices (e.g., mobiles and iPad. etc), whilst 30% use Internet/email and 24% prefer to use PC/laptop as indicated in Figure 5.7.

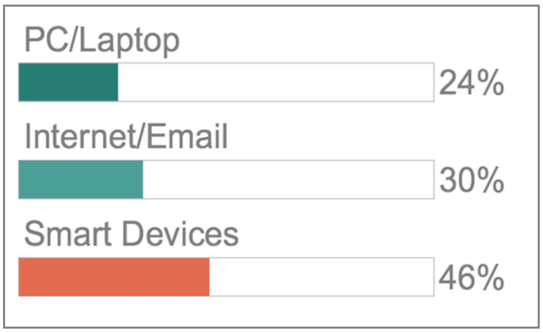


Figure 5.7: Preferences of Technologies Usage

Switching off appliances: 95% of participants liked to have a technology that switches off appliances automatically when not in use (e.g., heater, microwave, stove), as illustrated in Figure 5.8.

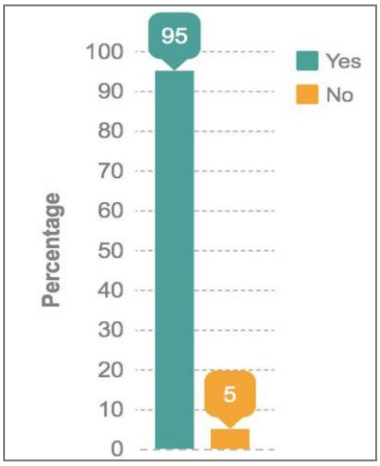


Figure 5.8: Switching off Appliances

Seeing daily activities: 50% of participants agreed that they would be happy for professional carers to see their daily activities data, although 23% of them disagreed (Figure 5.9).

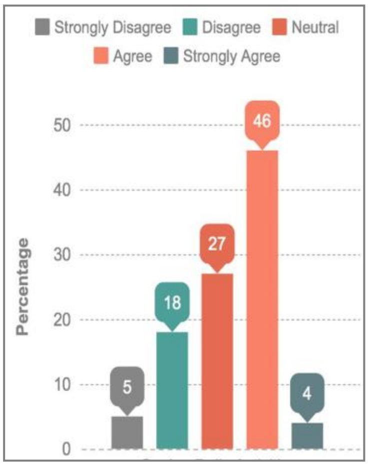


Figure 5.9: Seeing Daily Activities

Monitoring by camera: Figure 5.10 demonstrates that 53% of participants disagreed that they would be happy to be monitored by a camera, compared with 27% who agreed.

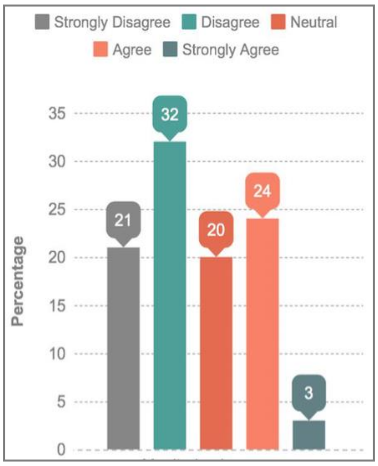


Figure 5.10: Monitoring by Camera

However, in the case of an emergency, 66% of participants would agree to turn on a camera for professional carers to check their safety, as shown in Figure 5.11.

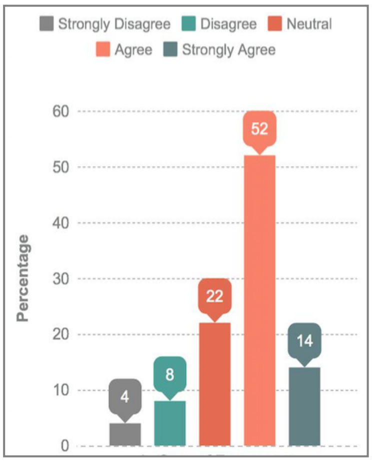


Figure 5.11: In Case of Emergency

AAL technologies: Figure 5.12 presents the categories of AAL mentioned in the literature review, and the results that were retrieved from the questionnaire. The results show that a high percentage (75%) of participants would favour the use the AAL technologies, such as Smart homes, assistive robotics, wearable and mobile devices, and e-textiles.

78% of participants preferred to use mobile devices, 78% of them wished to be assisted by assistive robotics, 77% would like to adopt the wearable sensors, 75% were interested in equipping their homes with Smart devices, and 68% would use the e-textiles.

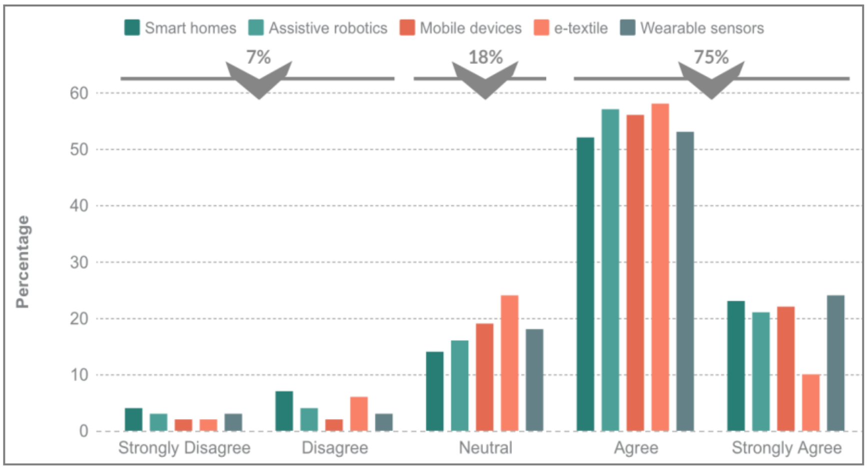


Figure 5.12: AAL Technologies

Using warning system: 93.3% of participants wished to use technology that has a warning system to remind them to do some activities, such as taking medication or drinking water, as shown in Figure 5.13.

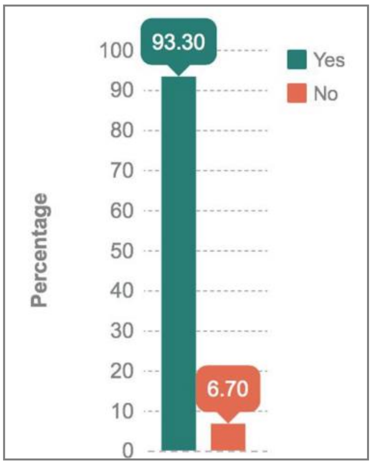


Figure 5.13: Using Warning System

Contacting care provider: 94% of participants agreed that they would be happy to have technology that immediately contacts the care provider by simply pressing a button, as presented in Figure 5.14.

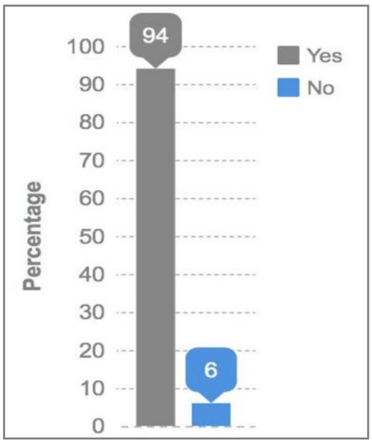


Figure 5.14: Contacting Care Provider

Training on technology: 80.5% of participants wanted to be trained in how to use new technologies that assist them in their daily activities, as described in Figure 5.15.

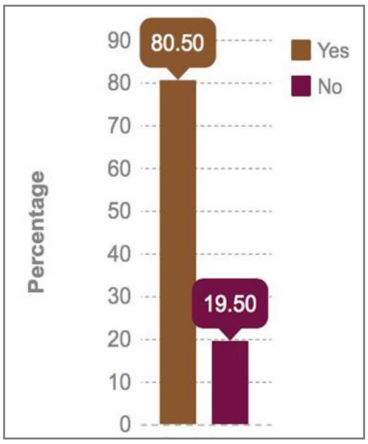


Figure 5.15: Training on Technology

Assisting by technology or humans: according to the questionnaire, it is quite evident that a 64% majority of the elderly agreed (52% agreed and 12% strongly agreed) that they would prefer to be assisted in their daily activities by technology communication rather than by human interaction (Figure 5.16).

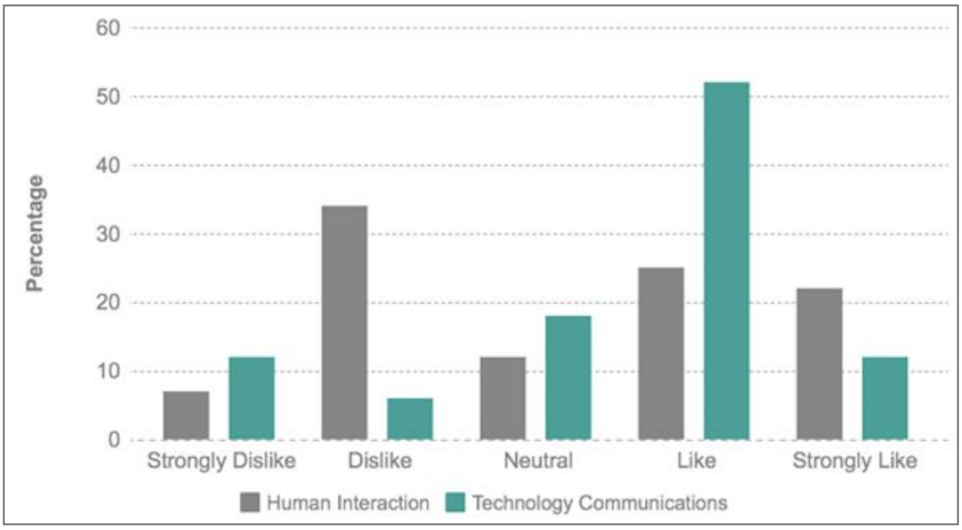


Figure 5.16: Assisting by Technology or Human

5.2.9.5: Professional Carers

The study showed that 76% of participants liked (58% liked and 18% strongly liked) using AAL technologies, whereas only 47% liked to be visited by a carer. However, 39% of participants disliked being seen by professionals compared with 8% who disliked using AAL technologies (Figure 5.17).

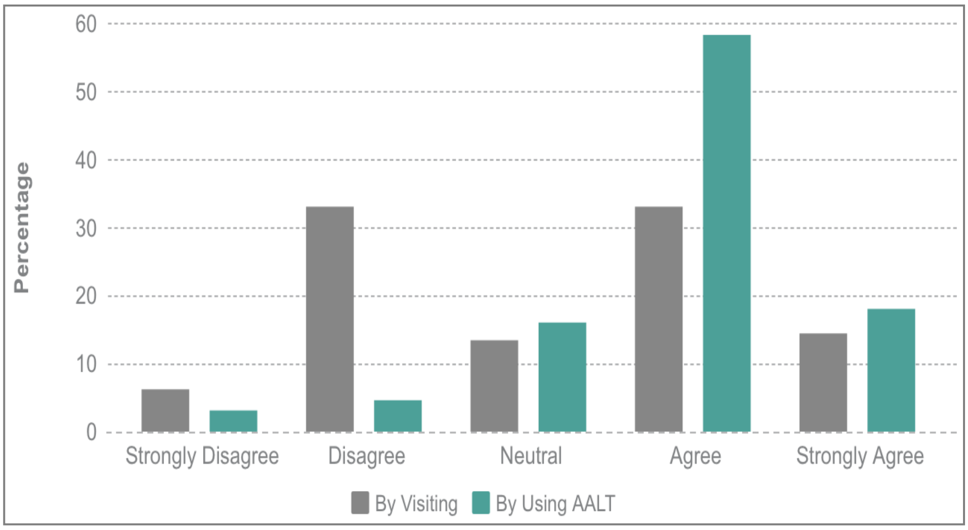


Figure 5.17: Visiting by Professional or by Using Technologies

Visit frequencies: as presented in Figure 5.18, the study reveals that participants who like to be visited by professional carer prefer to be visited weekly (30.9%) and 10.8% of participants like to be visited monthly. Furthermore, only 4.6% of participants like to be visited daily, while 53.6% did not answer.

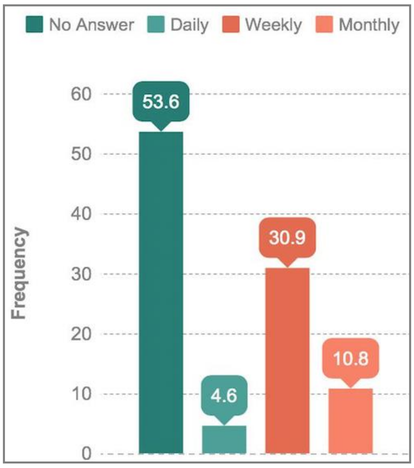


Figure 5.18: Visits Frequencies

5.2.9.6: Open-ended Questions

Two questions were designed to collect qualitative data, and the results of these questions were directly related to the limiting factors. The results were explicit, and we did not need to use any qualitative analysis. 94% of participants replied: ‘*none*’ when they were asked ‘*Do you have any suggestions for assisting you in your daily activities?*’ They suggested that technologies should provide exercise, therapy, entertainment and society involvement.

Other factors were extracted from the participants by asking the open-ended question: ‘*Are there any other factors that would affect your decision to use AAL technologies?*’ As indicated in Figure 5.19, 25% of participants expressed a wish to have AAL technologies for free, and 18% said that lack of awareness and training are factors that inhibit its adoption. Family acceptance is another factor that affects using AAL technologies, with 13% of respondents reporting this as a factor. Ease of use, if my health is weak, and respecting the culture, were also factors which have an impact on adoption, with 5%, 5% and 3%, respectively.

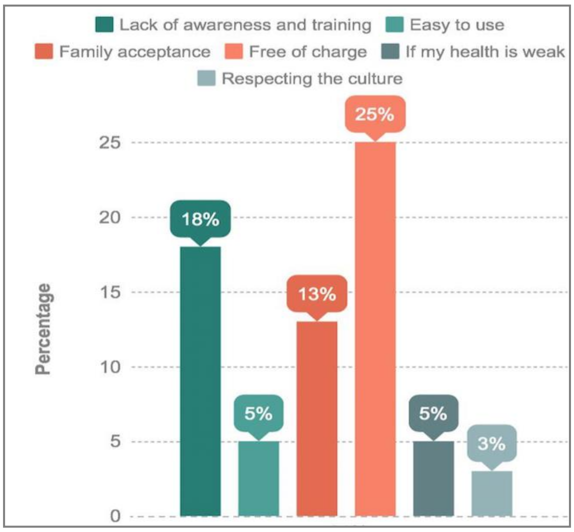


Figure 5.19: Other Factors Hindering Adoption

5.3: Discussion

In this study, we conducted a literature review about AAL technologies and the factors that affect the adoption of AAL technologies. Then, we investigated the willingness and intentions of elderly people in the KSA to accept and use AAL technologies, and we determined the factors that affect elderly Saudi Arabians from using AAL technologies. We found that most elderly people have positive attitudes towards technology and indicated sophisticated interests in adopting and using AAL technology. Moreover, the study aligned with the literature review regarding these factors and concerns.

Amr et al. (2014) stated that Saudi Arabian culture has traditional social values, which are completely different from other countries, regarding taking care of elderly people. Thus, as shown in Figure 5.1, only 8.8% of the elderly people lived alone. This percentage could be increased and supported by the use of AAL technologies.
AAL technologies provide elderly people with major benefits for living independently, by increasing their autonomy and assisting them in their daily activities. Therefore, AAL technologies promote and support the independence of elderly people in their own homes or in other preferred environments (Sun et al., 2009; Grgurić, 2012; Peruzzini & Germani, 2014).

We compared the results of the survey of this research with those of a 2015 Communications and Information Technology Commission (CITC) survey. The KSA CITC conducted a survey of 1,324 citizens, in order to ascertain their adoption of Smart devices. This survey showed that a significantly high percentage (82%) of mobile users had access to Smart devices (Communications and Information Technology Commission, 2015). The survey of this research included 194 elderly people, and its results showed that elderly Saudi Arabians, overall, were willing and intended to use AAL technologies. However, the survey revealed that there was a considerable number of elderly people (91 persons, 46.8%) still wanting to be assisted by human interaction, and 7.4% who wished to be visited by carers. This indicates that some of them were still unconvinced about the benefits of AAL technologies.

156 (80.5%) of the elderly who participated in the study were agreeable about the idea of being trained in new technologies. This is a good indicator for motivating healthcare providers to deliver AAL technologies to elderly people, and it shows that AAL technologies are ready for adoption and accepted by the elderly of Saudi Arabia.

53% of participants in the survey had concerns about individual privacy and personal health status, and 52% expressed concerns about personal data, while 21% did not have any concerns. The literature mentioned that privacy was indicated as an important factor for elderly people in the adoption of AAL technologies. Elderly people were also worried that their personal information would be mistreated and misused (Peek et al., 2014; Demiris et al., 2004; Grgurić, 2012). Demiris et al. (2004) stated that elderly people resisted being monitored by cameras and surrounded by these technologies, and this study indicated that 53% of participants disagreed to being monitored by a camera, while 27% of them agreed. Importantly, 66% of participants agreed for a camera to be turned on for professional carers to check their safety in case of emergency.

The review also showed that elderly people have concerns about security while using AAL technologies (Grgurić, 2012; Rashidi and Mihailidis, 2013; Peek et al., 2014), and the study demonstrated that home security is the second most reported limiting factor, with 85% of participants reporting this factor.

The results of the current study showed that home safety is the most significant factor that affects the adoption of AAL technologies (87%). The literature stated that elderly people are frequently unprotected from safety dangers and threats. Additionally, elderly people face many risks, and falling is considered as a major threat. Currently, fall detection is an important topic, but the problem with it is that sensors need to be worn constantly (Ding et al., 2011; Scanaill et al., 2006; Botia et al., 2012; Arshad et al., 2014).

In addition, this study indicated that usability of technology, size and weight intrusion of technological devices are also limiting factors, with 65%, 57% and 57%, reporting concerns respectively. This is also confirmed in the literature, as usability is a critical factor that plays an important role in adopting AAL technologies. The complexity of usability restricts elderly people from using technologies. Consequently, they are concerned about the user friendliness of AAL technologies, and they fear the difficulties of using it (Bevan, 1995; Peek et al., 2014; Peruzzini and Germani, 2014; Grgurić, 2012; Sun et al., 2010).

The results of the survey showed that 25% of participants wish to have AAL technologies for free, although cost is a major factor that impacts on elderly people's acceptance. Therefore, elderly people are not willing to pay for these technologies, due to their income circumstances, and expecting the support from governments. Smart homes can be limited by the cost of installation, repairs, maintenance, and energy (Peek et al., 2014; Steele et al., 2009; Chan et al., 2012; Arshad et al., 2014; Balta-Ozkan et al., 2013).

The study found that 18% of elderly Saudi Arabians said that lack of awareness and training are factors that inhibit the adoption, and the literature review mentioned that many elderly people are regularly frightened by technology, since they lack experience in selecting the right technologies that can satisfy their needs. Therefore, training and educating them are essential aspects of deploying AAL technologies, and the benefit should be clear to the elderly people who will use AAL technologies.

Further factors, derived from the participants, are family acceptance (13%), ease of use (5%), health (5%) and respect for the culture (3%), which all have an impact on the adoption. The literature also indicated that resistance to using technologies (AALIANCE2, 2014; Sun et al., 2009; Grgurić, 2012; Peruzzini & Germani, 2014), lack of human interaction (Sun et al., 2009; Wu et al., 2012), and interoperability (Grgurić, 2012; Balta-Ozkan et al., 2013) are considered to be factors.

5.4: Dimensions and Factors Framework Refinement (2nd Version)

According to the analysis of the questionnaire in this chapter, the factors and concerns that were indicated by the participants are: privacy, security, safety, usability, size, weight, ease of use, free of charge-cost, lack of awareness and training, family acceptance and culture. Some of these factors are not explicitly mentioned, like availability, trust, design and process, which were identified by the literature review in Chapter 4. However, safety and culture are new factors that were identified from the results of questionnaire. Therefore, safety and culture are added to the holistic framework that we designed in Chapter 4 as factors that affect adoption. Thus, the dimensions and factors of the initial version of the framework were kept as they indicated in Chapter 4. In fact, the second version of the framework is composed of a combination of factors and concerns that are extracted from the literature review and the results of this questionnaire. Figure 5.20 presents the two versions for developing the framework.

Figure 5.21 demonstrates the second version of the framework after refining.

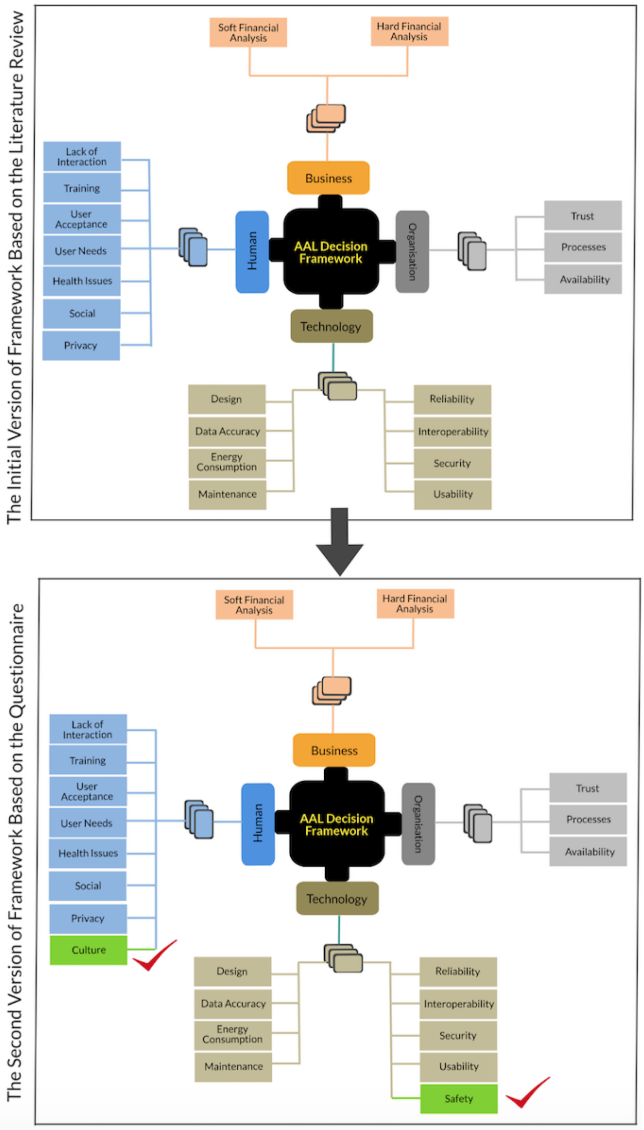


Figure 5.20: The Two Versions of Developing the Framework

Figure 5.21 demonstrates the second version of the framework after refining.

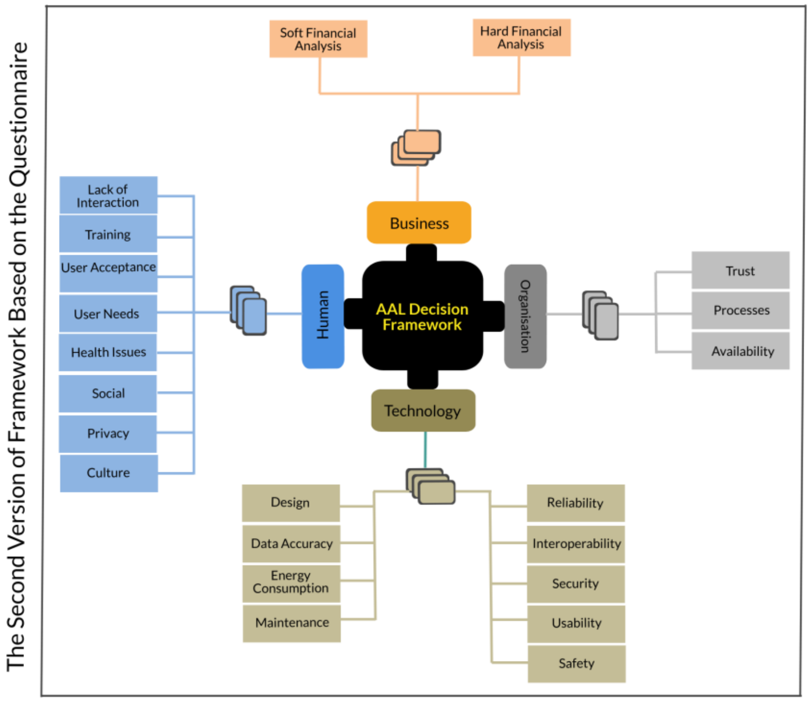


Figure 5.21: The Second Version of the Framework after Refining Based on the Questionnaire

5.5: A Community of Practice (CoP)

The aim of conducting a CoP is to identify the factors facing healthcare providers in the KSA in implementing and adopting Ambient Assisted Living technologies.

5.5.1: Definition

The Community of Practice (CoP) is a '*group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly*' (Wenger, 2005).

5.5.2: Description of the CoP

A CoP was conducted in the KSA in August 2015. The Arabic language was preferred, and the session was recorded. Four CEOs and an Executive Vice President of healthcare providers were involved, and the size and complexity of the organisation are outlined as follow:

- Salam Home Health Care delivers a comprehensive range of home healthcare services. It has more than 100 staff, approximately 75 nurses, and more than 10 physicians. Its services deliver to more than 2,000 people
- Saudi Health Services Co has been in the health market since 1984. It provides a

diversity of medical utilisations and equipment of the latest technology across Saudi Arabia

- Sela Medical aims to improve healthcare services in Saudi Arabia by operating and managing facilities. It started in 2005 and promised to spend SR 20 million on each project for the International Renal Care Centres for treating End Stage Kidney problems.

The researcher started with an introduction about AAL technologies and how AAL technologies support elderly people who are in good healths but need some help to do some daily activities such as shopping, cooking, or cleaning, providing a definition of elderly people (Hossain et al., 2014).

The researcher mentioned that two tasks would be performed in relation to this project. Firstly, a questionnaire would be designed to extract the attitudes and perceptions of Saudi Arabian elderly people. Secondly, CoP study would be conducted with healthcare providers to elicit the factors and challenges that face them in deploying AAL technologies in KSA.

The researcher stated the objective of this project, which is to offer elderly people a secure and private environment, providing quality of life and more time in their desired home. This is because there is a large increase in the aged population in Saudi Arabia, which will be increasing in the next 50 years.

The researcher indicated that there are globally some factors, which relate to privacy, security, cost, lack of awareness, lack of experience, etc. These factors may or may not be the same in the KSA; therefore, this CoP study was organised to share the factors and challenges that affect them according to their experience of working in the KSA in providing different technologies in relation to healthcare services to the elderly.

The participants mentioned that there is a challenge with the growing ageing population in the KSA. One of them indicated, '*the Saudi government faces a huge trend in ageing population in the future*'. Therefore, we should notify people, organisations and delegations about this high increase in the ageing population. They said that the infrastructures are not ready to deploy such technologies (AAL technologies).

Some of the important concerns of the participants are outlined as follow and have been annotated by the researcher from the statements and comments they made:

- **Concern 1:**

There is no continuum of care, but if it is found, it may be marginalised usually by few organisations. It is scattered. In the long term, home care, day care, and hospice are not essential parts of the healthcare system; however, these have just started but will never meet the future demands. In addition, nursing home care is not offered regardless of culture. For example, one participant said, '*my father had a stroke; he is in the ICU for a week. I own a company; thus, I provided him with nursing*'.

This proposed project should spread and be applied all over Saudi Arabia, because today, if we are unable to take care of our parents, who will take care of us in the future? There are many changes in demographics and economies. Thus, this project is needed.

- **Concern 2:**

The practise of elder care by family members will change in the future. The parents will no longer live with their children. We notice that when children get married, they move to their own homes. While parents live in their homes independently, there are no services provided for them, and no one can take care of them.

There are not enough specialists to work with elderly people and take care of them. We should graduate more students who major in this field. Furthermore, healthcare providers may not be able to deliver technologies such as these to elderly people in the KSA. This means we cannot bridge the gap to meet the needs of the elderly. Elderly people may not be able to pay for these technologies.

- **Concert 3:**

Smart watches are available in the KSA, and athletes use them. Furthermore, there are more advanced technologies for those who suffer from some diseases such as cardiac disease. However, the elderly and their families can use these kinds of technologies. Furthermore, we must study the cultural factors regarding their use. We might find a problem in convincing families and the elderly to adopt them.

There was a concern raised regarding cost, but it will be great if the Ministry of Health (MOH) adopts this kind of service and technology and provides them to the elderly. Indeed, the MOH pays for whoever has diabetes to use some devices to measure the level of diabetes. This could be a national project that would be useful.

- **Concern 4:**

Elderly people who live alone and are supported by the Ministry of Social Affairs, which has a program for visiting the elderly, are categorised into two groups: 1) those who do not have family to take care of them but live in their homes, and the Ministry provides them with some services such as cleaning the home, buying their groceries, giving rides to visit relatives, and providing some entertainment, etc.; 2) those who are deserted and who move into social care homes for care. One participant suggested using this project to assist elderly people to start using AAL.

- **Concern 5:**

The care of the elderly is limited, and the Social Affairs Ministry takes care of only the elderly who are so old and who do not have families or relatives. In the KSA, we do not have enough information about the elderly, which causes a lack of information among the elderly, healthcare providers, the Ministry of Health and the Ministry of Social Affairs. Elderly people will face problems when using these technologies and cannot pay for them. Therefore, they should be trained in them and receive financial support from the Saudi Government.

- **Concern 6:**

Resistance to the use of technology is one of the most significant factors affecting the adoption of technology by elderly people. One participant mentioned that '*we are facing a problem to convince elderly people who have diabetes to wear a strap that can manage it*'. Thus, the MOH limits this technology to elderly people who are educated and trained. However, this might change in the future because the new generation of our population is well educated.

- **Concern 7:**

There is no general strategy for the government, every Ministry works alone, and '*it is easy to destroy a project because another leader comes on the Board*'. We have a five-year vision, which it is not enough to plan, implement, and achieve. We should have a 20-year plan and have the same vision and objectives.

- **Concern 8:**

Awareness is very important among three categories, which are the elderly people who will use these technologies, organisations who will do the implementation and the communities. Therefore, training is a factor that affects adoption.

- **Concern 9:**

Regulations and processes should be re-studied and redeveloped to meet the new demands and needs. We should admit that there is a need for these kinds of technologies. Thus, it is necessary to have a clear system that guides the organisation for adopting these technologies and providing them for elderly people.

- **Concern 10:**

Privacy and security are very critical. However, once elderly people discover the benefits of these technologies, they will change their mind about these two concerns. Yet, privacy and security can affect the adoption of these technologies.

- **Concern 11:**

The availability of business and their desire to provide such technologies is an essential factor that can affect adoption. Many concerns can be raised regarding the availability of these technologies and the benefit and profits that can influence organisations to adopt them. One participant stated that '*we have adopted home care since the 1990s, but we are still at the beginning and have not reached a successful stage*'. There are no motivations to adopt these technologies because of the resistance that we as healthcare providers face. The cost of providing these kinds of technologies is very high at the beginning of any project; therefore, the government should support and provide it to elderly people.

- **Concern 12:**

The infrastructure is not yet ready for adopting these technologies such as Smart homes. Hence, it is necessary to develop standards and regulations that can assist the adoption of these technologies to meet the needs of elderly people. Municipalities are required to include these standards in newly established homes, roads, governmental buildings, etc to be ready for such technologies.

5.5.3: Results of the CoP

According to the description of the CoP, many factors that face healthcare providers in the KSA can be identified. The first factor is the cultural factor that may discourage the elderly from using AAL devices to facilitate improving the quality of care. This finding is consistent with the findings in the literature review where cultural factors were considered a major cause of resistance among the elderly in using AAL.

Another critical challenge identified was the cost of the device; most of the respondents agreed that most of the elderly population can not afford to buy devices. It was suggested that the government should facilitate the elderly in purchasing AAL devices to reduce the expense of implementation and missing the assistance of family members. Most elderly people tend to be isolated from their relatives and children, resulting in difficulties in taking care of their healthcare needs.

Resistance to using a technology is considered a factor that affects the adoption of technology by elderly people. They have insufficient knowledge about the benefits that are provided by using these technologies. Therefore, lack of training among the elderly on the use and application of AAL is a significant factor; one respondent noted that they ought to be provided with training on the use of the devices.

Another factor is strategy. There is no general strategy for the government that can be implemented by ministries to have the same vision and objectives regarding the adoption of AAL technologies for elderly people. This leads to a lack of regulations and processes to be applied and followed when adopting these technologies by elderly people and healthcare providers indicating a need for a ‘strategic vision’.

The participants indicated privacy and security as major factors for elderly people at the beginning of adopting AAL technologies. They mentioned that elderly people are worried that their personal information could be mistreated or misused.

Organisations that are able to provide AAL technologies have a concern about the success of this business. They indicated that the support from governments and users’ acceptance are drivers for them to adopt and deliver these technologies.

Finally, they mentioned that infrastructures should be investigated and redesigned to meet the needs of AAL and other technologies.

5.6: Dimensions and Factors Framework Refinement (3rd Version)

The results of the CoP indicated that the concerns/factors that affect the implementation of AAL technologies by the healthcare provider are: culture, cost, user needs, resistance, training, strategy, regulations and processes, privacy and security, user acceptance and infrastructure. Most of them are mentioned in the literature review and indicated by the questionnaire except resistance, strategy, and infrastructures. Therefore, these three factors were added to the holistic framework, and the three versions for developing the holistic framework are illustrated in Figure 5.22.

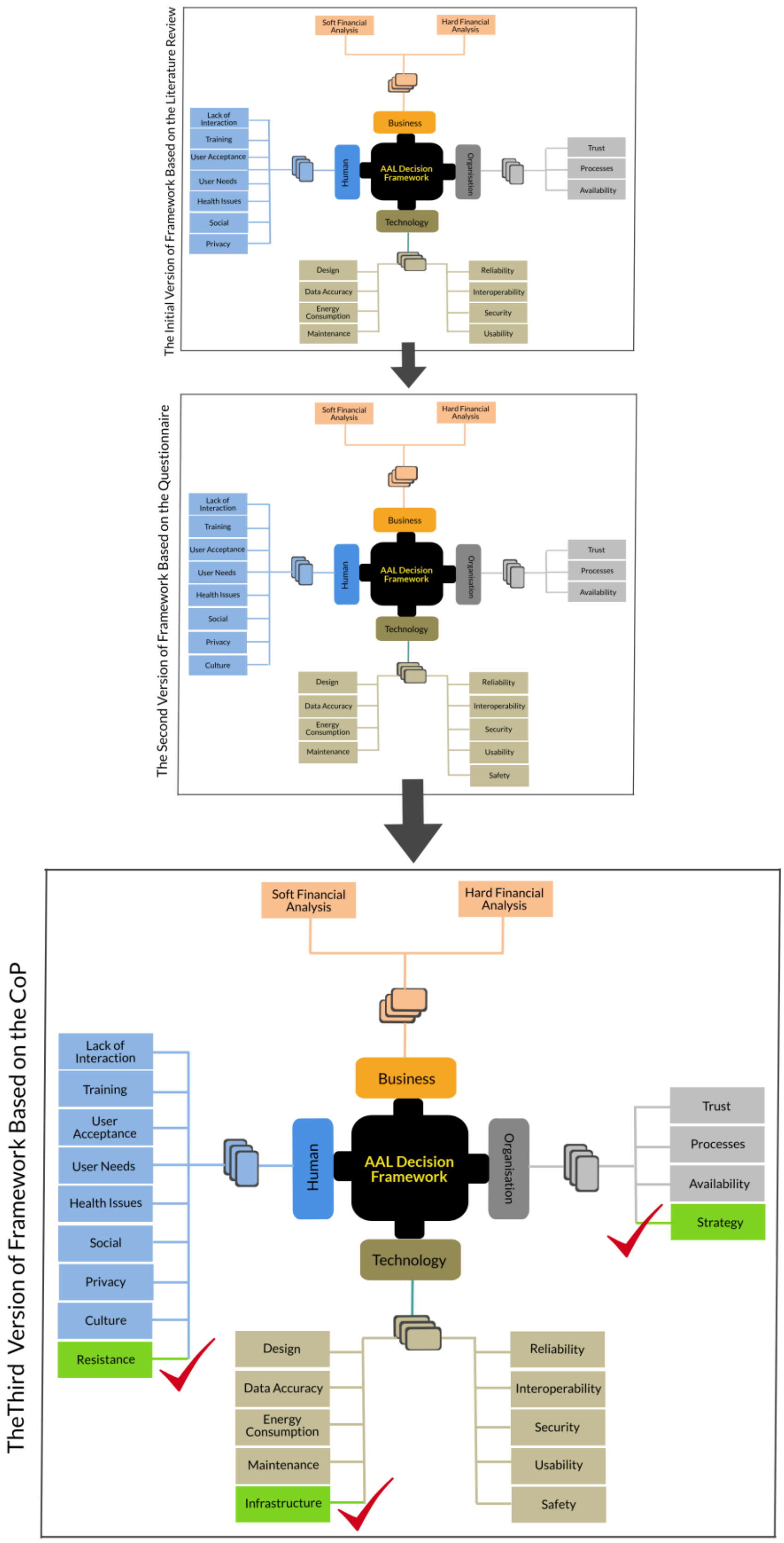


Figure 5.22: The Three Versions of Developing the Framework

The final version of the development of the holistic framework for decision making for using AAL to support stakeholders is shown in Figure 5.23.

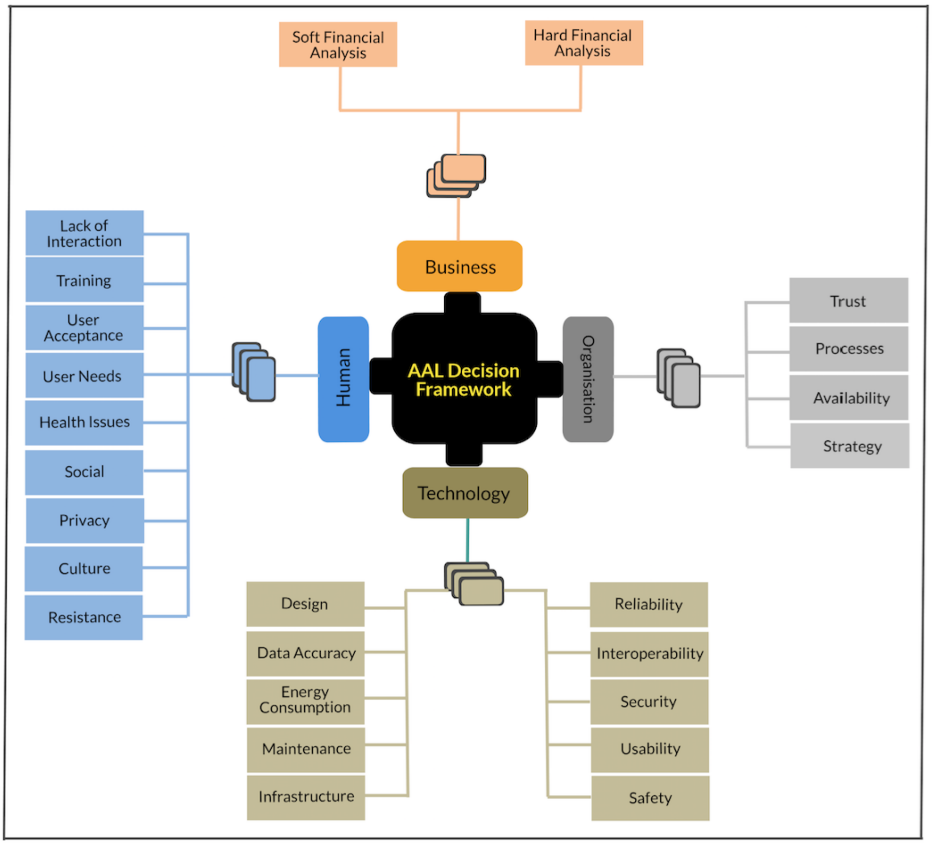


Figure 5.23: The Holistic Framework for Decision Making for Using AAL to Support Stakeholders

5.7: Conclusion

AAL, is an essential aspect of providing elderly people with independent living and extension of life, as well as decreasing the cost of healthcare. Two primary studies were conducted in Saudi Arabia, which were a quantitative approach using a questionnaire to investigate the perceptions and attitudes of elderly people in the KSA and factors affecting adoption, and a qualitative approach using a CoP study to identify the factors that restrict the implementation of AAL technologies by healthcare providers.

The participants in the questionnaire were 60 years old and over. An online questionnaire was the instrument used for this study.

The results showed that participants mostly need assistance with shopping, cooking, washing, and cleaning. The findings demonstrated that the elderly people are significantly willing and intend to accept and use AAL technologies. They showed that AAL technologies have the potential to be adopted by the elderly. Overall, the results showed that most elderly people are not resistant to using AAL technologies and are ready to be trained in AAL technologies.

The findings demonstrated that participants have some concerns regarding individual privacy, health status and personal data, with 53%, 53% and 52% expressing concerns, respectively. Nevertheless, 50% of participants agreed to allow professional carers to see their daily activities data, while 23% of them disagreed.

The study showed that there are some factors that affect the adoption of AAL technology, which are: home safety, home security, usability of technology, size intrusion and weight intrusion of technological devices. In addition, the results show that other factors can inhibit the adoption of AAL technologies, such as: whether AAL technologies are costly, lack of awareness and training, family acceptance, ease of use, health and respecting the culture.

A CoP was conducted with healthcare providers in the KSA in order to identify the factors that could affect the implementation of AAL technologies in KSA. They indicated that culture, cost, user needs, resistance, training, strategy, regulations and processes, privacy and security, user acceptance and infrastructures are the most significant factors that affect the adoption and implementation of AAL technologies.

The decision making holistic framework for using AAL to support stakeholders was refined based on the results of this questionnaire and CoP. The factors that were extracted from the literature review in Chapter 4 were modified by adding safety, culture, resistance, strategy and infrastructures, which were suggested from the questionnaire analysis, and the CoP discussion.

Chapter 6 discusses the proof of concept from the experiments and analysis of results. It includes the definition of the heart rate and Smart watches. A comparison between Smart watches, tracking systems and camera surveillance will be presented. Then the results of conducting the experiment are discussed.

Chapter 6: Proof of Concept, Experimentations and Results

6.1: Introduction

In the previous chapter, we developed a questionnaire to extract the perceptions and attitudes of elderly Saudi Arabians and identify the factors that affect the adoption. The analysis of the questionnaire indicated that elderly people in Saudi Arabia are willing and intending to adopt and use AAL technologies. They identified several factors that affect the adoption of AAL technologies, which are privacy, lack of awareness and training, family acceptance, culture and cost. Also, we conducted a CoP with healthcare providers to identify the factors that affect the implementation of AAL in the KSA.

This chapter discusses the definition of heart rate (HR), the normal heart rate and the expected maximum and minimum HR when working. The types of technologies that can be used to monitor elderly people at home are explained. Experiments have been undertaken in order to validate these technologies in Saudi Arabia, the United Kingdom and Germany. Smart watches, chest straps, Bluetooth beacons, ZigBee and cameras were used in these experiments.

The results of these experiments showed that these technologies are appropriate for monitoring elderly people at their homes, and to allow relatives, friends, and healthcare providers to monitor them when abnormalities occur, and to help to prevent medical issues. However, some studies indicated that some Smart devices might give inaccurate readings, which could lead to harmful issues.

6.2: Rationale Behind Conducting Experiments

The conceptual model is based on the use of technologies, which can be determined by the elderly person's requirements. Therefore, there is a need to ensure that technologies are reliable and can be adopted. The aim of developing the conceptual model is to monitor an elderly person at home and provide him/her with quality of life and be independent. Thus, it is important to conduct experiments using technologies that can be considered to solve most concerns and issues among elderly people. According to the literature review, heart failure and falls are the most common causes that lead to medical issues for elderly people. Hence, the Smart watches, tracking system, and surveillance camera were chosen to be the technologies used to measure the heart rates, tracking elderly person at home, and monitor him/her in emergency cases.

The heart rates monitoring was conducted in UK, the KSA, and Germany. The experiment conducted in Germany was to calibrate the Smart watch to chest strap and Pulsoximeter, which were available at their department and provided valuable insights. The experiments were conducted in different regions in UK and KSA was to demonstrate that the results could be monitored in different regions and countries.

6.3: Motivation for Using Smart Watches

Heart rate (HR), or pulse rate, represents the number of times a heart beats each minute. The determination of what is a normal heart rate depends on many factors, such as age, body size, movement, exercise, and heart conditions. A normal heart rate can be between 70 and 100 beats per minute (bpm) (British Heart Foundation, 2014). In some cases, normal hearts can have abnormalities in the system of electrical heart and this cause arrhythmias. The types of arrhythmias are bradycardia, when the heart beats less than 60 bpm, and tachycardia, when the heart beats more than 100 bpm. However, sometimes when these two types occur, this may not be a threat, and exercises can increase heart rate (National Health Fundation of Australia, 2016).

The maximum heart rate can be calculated using the equation '*220-age'* (British Heart Foundation, 2014). When exercising, the heart rate can be between 50% and 70% of the maximum heart rate, as shown in Figure 6.1 (British Heart Foundation, 2014). To the best of our knowledge, the minimum acceptable heart rate has not been mentioned in any studies. We used the equation '*220-age*' for the maximum heart rate.

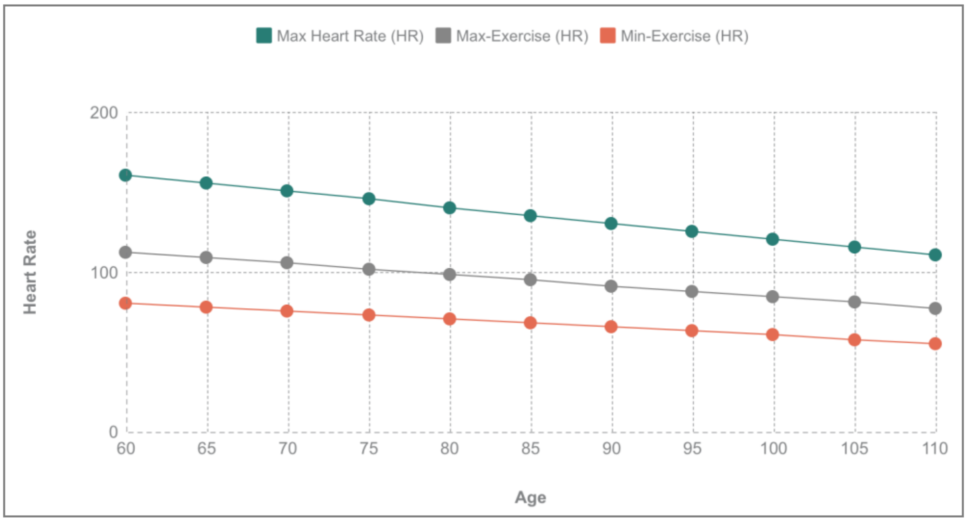


Figure 6.1: Expected Maximum Heart Rate and Maximum and Minimum Heart Rate when Exercising (calculated by this researcher)

The World Health Organization reported that non-communicable diseases are common among elderly people, including, heart diseases, dementia, cancer, and chronic respiratory disorders. In general, elderly people are vulnerable to loss of vision, hearing and mobility (World Health Organization, 2015).

In the United States (USA), by 2030, it is projected that more than 8 million people will be diagnosed with heart failure (HF). The cost of HF treatment in 2012 was US $31 billion, and it is estimated that it will reach $70 billion in 2030. The proportion of total HF expenditure for people who are 65 years of age and older in the United States, is expected to increase from 69% in 2012 to 80% in 2030 (Heidenreich et al., 2013).

In the USA, in 2009, 75% of patients who were hospitalised for HF were 65 years and older, and the cost of treatment was US $37.2 billion (Samala et al., 2011). In the UK, cardiovascular disease (CVD) is the second leading cause of death, accounting for 28% of fatalities in 2014. The cost of treating CVD in England was more than £6.8 billion in 2012 (Townsend et al., 2014).

In Ireland, the proportion of elderly people who suffer from chronic diseases such as diabetes, heart disease, musculoskeletal pain and hypertension, is expected to rise to 40% by 2020 (Age Action Ireland, 2013).

In Australia, a study reported that the most common health issues among elderly people are arthritis (49%), hypertension (38%), hearing loss (35%), heart stroke and vascular diseases (22%), and diabetes (15%) (Australian Institute of Health and

Welfare, 2014).

In the KSA, a study was conducted by (Al-Modeer et al., 2013) and indicated that the most relevant health issues for elderly people are hypertension (59.1%), diabetes mellitus (57.3%), stroke (34.9%) and dementia (28.5%). On some occasions, elderly people are left unable to obtain beds in hospitals (Ministry of Health, 2013a). HF is a major concern for elderly people in the KSA (AbuRuz et al., 2015; Albugami et al., 2015).

Therefore, there is a need for a technological solution, to monitor the heart rate of elderly people while they are at home and prevent medical issues that could happen if immediate actions are not taken.

The chest strap is a traditional, proved and validated heart device, widely used to monitor heart rate. It is connected to a watch, and delivers reliable and consistent data (Hesse et al., 2014). However, using a chest strap can limit the mobility of the user, may not be comfortable if worn for the whole day, and it could cause problems for the user's health. The chest strap was chosen to be tested against the Smart devices selected for this study because it is an accepted instrument for measuring heart rate, and it can be benchmarked for comparison purposes (Cleveland Clinic, 2017; Ge et al., 2016).

The motivation for the wearable devices' experiments arose because some Smart devices use accelerometers to monitor elderly people. Therefore, if an elderly person is at rest, for instance watching TV, heart failure might not be recognised by the device. A question was raised in this research regarding the capability of determining whether an elderly person is alive or dead when he/she is watching TV at a home equipped with a variety of sensors, such as for emotion, blood pressure and temperature. Therefore, for overcoming this problem, both Smart watches and Chest straps were used in the experiments. Smart watches are computing devices whose operating systems offer different capabilities, and their demand is increasing in the customer market (Xu & Lyons, 2015; Lyons, 2015). They are more user friendly and are preferred by users if they need to be worn for a long time (Lee & Gorelick, 2011).

6.4: Smart Watches

The development of wearable devices is advancing significantly (Poh & Kim, 2012).

A study of 16,000 customers, conducted by Forreste in 2014 in the USA and UK indicated that one third of participants preferred to use wearable devices. The USA market share of wearable devices was projected to be $28.7 billion in 2016 (Weinswig et al., 2016). Therefore, instead of encouraging elderly people to adopt a technology with which they do not feel comfortable with, we considered the results of a questionnaire distributed in the KSA, which demonstrated that KSA elderly people prefer wearable devices, as shown in Chapter 5 and in (Alsulami & Atkins, 2016).

Smart watches have been used to monitor heart rate (Zhang, 2015) through the use of light technology sensors that measure the rate of blood flow, as controlled by the pumping action of the heart (Rios-Aguilar et al., 2015). Smart watches have been used in many applications. A study found that fatigue-driving causes 10-30% of road deaths and sleeping while driving is also one of the main causes. Therefore, a Smart watch was used in this study to detect sleeping while driving (Rios-Aguilar et al., 2015).

Smart watches were also used by Highway England in major trials as follows: the normal speed limit for motorway roadwork maintenance in the UK is 50 mph. Trials were conducted by Highways England because of concerns of unnecessary motorway delays and pollution issues. Consequently, 36 participants were provided with heart rate monitor watches, and tests were conducted, which found a decrease in the heart rates of drivers while they drove at 55mph and 60mph through roadworks (BBC News, 2017).

Many Smart watches are currently available on the market. Therefore, we investigated the features of some Smart watches in terms of their monitoring heart rate, battery life, price and apps. Any Smart watches that had just the Android app were excluded from the comparison, because the devices that the researcher has are iOS apps (e.g., iPhone, iPad). Sony and Motorola are used to monitor heart rate, but they were excluded from this research because they have only the Android app.

Table 6.1 provides a comparison of a variety of Smart watches.

Table 6.1: Comparison of Smart Watches

Device	Application	Heart rate monitor	Battery life	Amazon Price	Medical	Sport	Pro	Cons	Reference
Samsung Gear S3 	Android, iOS	Yes	<1 day	£279.89	No	Yes	•Built in GPS •Attractive design •Water resistant	•Limited Apps •Battery needs to be improved •Complicated to be connected to iOS	(El-Amrawy & Nounou, 2015; Pie, 2016)
Philips 	Android, iOS	Yes	4 days	£249.99	Yes	Yes	•Built in GPS •Data Accuracy •Good battery life •Lightweight •Water resistant	•Limited Apps •Design •Manually sleep tracking	(Philips, 2016; Edwards, 2017)
Fitbit Surge 	Android, iOS, Website	Yes	7 days	£169.99	No	Yes	•Built in GPS •Automatic sleep tracking •Solid battery life •Constant heart rate monitoring	•Design •Syncing issues •Not waterproof	(Fitbit, 2015a; Www.fitnessrocks.org, 2016)
Garmin Vívosmart 	Android, iOS, Website	Yes	5 days	£99.99	No	Yes	•Built in GPS •Good design •Water resistant •Good battery life •Constant heart rate monitoring	•Garmin Connect app is disordered •Unable to respond to notifications	(Garmin, 2015; Easton, 2017a)
Garmin Forerunner 35 	Android, iOS, Website	Yes	Up to 13 Hours	£139.00	No	Yes	•Built in GPS •Water resistant •Acceptable battery life	•Inaccurate heart rate •Slow signal •Design	(Wareable, 2015; Metareviews, 2017)

Apple Watch Series 1 	iOS	Yes	1.5 days	£215.00	No	Yes	•Attractive design •Secure •More comfortable •Many Apps •Enable notifications	•Average battery life •Expensive •Inbuilt in GPS •Limited functions to IPhone	(El-Amrawy & Nounou, 2015; Colon, 2016)
Adidas 	Android, iOS	Yes	4 Hours Training Mode	£83.00	No	Yes	•Built in GPS •Sweat proof	•Short battery life •Large	(BBC, 2013; Gibbs, 2013)
TomTom Spark 	Android, iOS, Website	Yes	5 Hours using features	£189.99	No	Yes	•Quick Built in GPS •Reliable heart rate data •Water resistant •Automatic sleep tracking	•Poor battery life •Software needs more works •Pairing issues	(Sawh, 2016)
Polar M600 	Android, iOS	Yes	Over 5 Hours using features	£265.00	No	Yes	•Built in GPS •Water resistant •Accurate GPS and heart rate	•Poor design •Poor battery life •Charging is a little complicated	(Easton, 2017b)

Philips Smart watch, Garmin Vívosmart and Surge-Fitbit were selected for conducting heart rate experiments during this research. The reasons for choosing the Philips Smart watch were that it is promoted as a medical approved device, with a battery life stay of 4 days. A study conducted by Hendrikx et al. (2017) indicated that a Philips Smart Watch can be used as a medical tool to measure resting heart rate. Garmin Vívosmart was chosen because of its battery life stay of 5 days, and of its price, and Surge-Fitbit was also chosen for the same reasons. Furthermore, in 2015, Fitbit was considered a leading company in developing Smart bands, with more than one third of the market, compared to Xiaomi, Apple, Samsung and others (de Arriba-Pérez et al., 2016). Among the selected Smart watches, Garmin Vívosmart can be connected to a chest strap. Thus, a Garmin chest strap was selected for these experiments.

6.5: Heart-Rate Monitoring Devices

➢ System Requirements and Components

Two concerns were considered important in choosing the Smart watches: the presence of heartbeat sensors and compatibility with other devices.

The Internet is the basis for the use of the devices. A Bluetooth network is used to connect the Smart watch with the mobile application installed on a Smart phone or computer. This assists in synchronising the data from the Smart watch to the mobile app. The Smart phone uses a wireless connection to transfer data from the mobile app to the web portal.

➢ Mobile App

The mobile app is an application, built by the Smart watch provider (Garmin, Fitbit, Philips, etc.), to offer various services. In this study, the mobile app was installed on the elderly person’s Smart phone. A user name and password were created on a login screen upon receipt of the device.

➢ Online Portal

The online portal is a website that allows users to visualise all activities and data whenever needed. For the current study, we focused on data related to heart rate. The data were uploaded to the online portal via the mobile’s app.

6.5.1: Experiment-1: in United Kingdom

The aim of the experiment was to provide a technology that elderly people in Saudi Arabia could use to monitor their heartbeat and thus manage issues associated with heart failure.

➢ **Problems**

Many Smart watches are currently available on the market. We investigated the features of these Smart watches in terms of the monitoring of heart rate. We found that most of them use applications and websites to visualise the heart rate data of the elderly person being monitored, but no specific actions can be taken if an abnormal heart rate occurs.

➢ **Experimental Case**

An elderly person (principle supervisor), over the age of 60, was given a Smart watch and monitored in two town locations during his normal activities, including when he was driving. This elderly person was first monitored for seven days, February 18–24, 2016, in Stafford and Chepstow in the United Kingdom. Figure 6.2 presents the 24-hour maximum and minimum heart rates for the seven days. The maximum rate was 149 bpm, and the minimum rate was 65 bpm.

Figure 6.2: Heart Rate for an Elderly Person (18-24 February 2016)

Through the experiment, abnormalities were noticed in that day, which were on February 18, 19, and 20, as shown in Figure 6.3.

Figure 6.3: 24-Hour Heart Rate Data (18- 20 February 2016)

Thus, we contacted this elderly person to determine the reasons and learned that the abnormal readings were due to the person exercising, which caused an elevated heart rate. The minimum rate was roughly as described in the literature review.

This elderly person was then monitored for another five days, May 20–24, 2016, in the towns of Stafford and Chepstow in the United Kingdom.

Figure 6.4 presents the daily maximum and minimum heart rates for the five days, from 7:30 a.m. to 11 p.m. every day. The maximum rate was 197 bpm, and the minimum rate was 58 bpm.

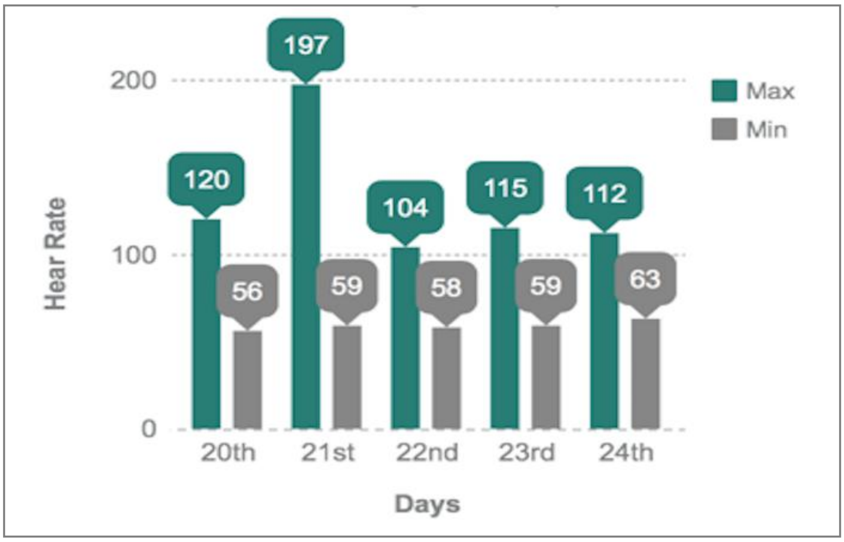


Figure 6.4: Heart Rate for Elderly Person (20 -24 May 2016)

On May 21, 2016, the heart rate was 197 bpm, as shown in Figure 6.5, which is quite high, indicating an abnormal occurrence. We contacted the elderly person immediately after noticing the high pulse and learned that the elderly person was rushing to meet a deadline. However, the heart rate was within the normal range on all other days.

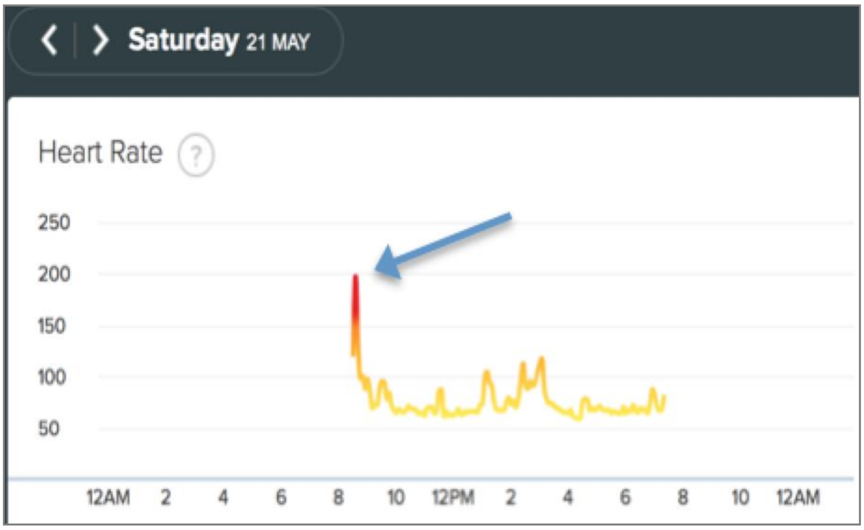


Figure 6.5: Heart Rate for Elderly Person (21th May 2016)

The elderly person was then monitored, using a web portal, via a laptop or Smart phone from three different countries: 1) Stafford, United Kingdom, 2) Jeddah, Saudi Arabia, and 3) Los Angeles, United States. The experimental process is illustrated in Figure 6.6.

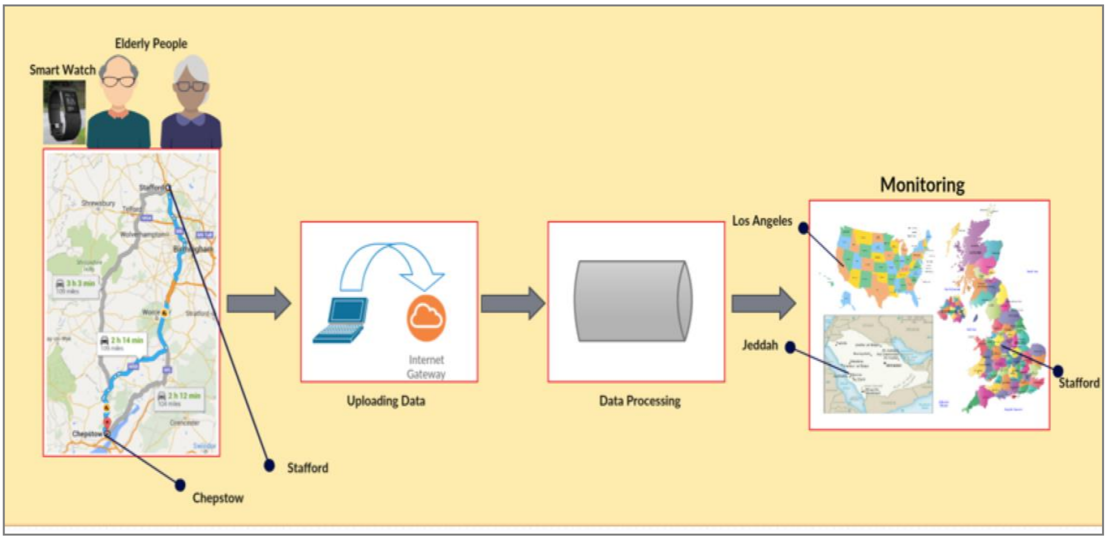


Figure 6.6: The Process of Monitoring an Elderly Person

However, during the monitoring, the results show that we were only able to visualise the heartbeat data. The system currently does not take action when an abnormal event occurs. Helpful actions could include sending an alert message to family, relatives or health-care providers; dispatching a doctor or nurse; or dispatching an ambulance.

Clearly, these types of systems require families, relatives and health-care providers to monitor the elderly person's heart rate constantly, which can be extremely time consuming. In practice, Smart watches are not linked to any support system of healthcare providers, and are mainly used to display visual data to the individual.

6.5.2: Experiment-2: in the Kingdom of Saudi Arabia

The aim of this experiment was to observe the ability, intention and willingness of elderly persons to adopt the technology. The experiment was conducted by the researcher's mother, in 2016, to monitor her heart rate, using a Smart watch for two months starting on 20th of June, until 20th of August 2016. The Smart watch has a Bluetooth, which is connected to a phone. The data is transferred via a Bluetooth to an app and then to the Cloud. The app was installed on the author's phone. The data could be monitored via the app or an online portal.

➢ **Observations about the experiment**

- Some of the data were missing, for example because of the changes in the location of wearing the watch, or of the battery's life.
- The elderly person was unable to fix the issue of the watch's location, and it was

sometimes hard to charge the watch.

- The elderly person had problems with the language of the Smart watch
- Changing the Bluetooth setting is another problem facing the elderly, which leads to the monitoring not being ‘real life’. The data can then be synchronised with the app as soon as the Bluetooth turns on. On some occasions, the elderly person turned the Bluetooth off, which affected the connection between the Smart watch and the phone app
- The watch was comfortable for the elderly person
- This experiment allowed us to monitor the elderly person’s heart rate 24/7. Therefore, we found that the monitoring can work simultaneously with other systems and there is no overlap between the results of these systems.

6.6: Experiments

The aim of this experiment was to measure the accuracy of visualised data between (calibration) different Smart watches.

➢ Location

The experiments were conducted in England on March and October 2017; and in Germany on December 2016, at the Department of Mechatronic, Cooperative State University, Stuttgart in December 2016.

➢ Instruments

To conduct these experiments five Smart devices were selected. The aim of this experiment was to measure the performance and accuracy of these devices. The five devices are presented in Figure 6.7 and are described as follows:

- Surge (Fitbit)

This is a Smart Watch that is able to track many activity types, such as the number of steps taken, the nature of the ground surface, the route, the heart rates, etc. (Fitbit, 2015b).

- Vívosmart® HR (Garmin)

This is a watch-like Smart-device that can track many activity types, such as the number of steps taken, the nature of the ground surface, the route, the heart rates, etc. (Garmin, 2015).

- Pulsoximeter

This is a device used to measure the pulse and the holder’s blood oxygen saturation levels. When used, this device is connected to a laptop via a wired cable (World Health Organization, 2011).

- Chest Strap (Garmin)

This device consists of two parts: a fabric strap and a plastic heart rate module. Both are used to monitor the holder’s heart rate by being worn on the skin, transferring data directly via the Smart watch (Garmin, 2013).

- Philips Health Watch

This device is used for tracking activity, to monitor the holder’s calorie burns, sleep habits, the heart rate, and other key metrics of the holder’s cardio condition. To measure these continually, this device uses a tri-axial accelerometer, to measure motion, as well as green Light-Emitting Diodes (LEDs) and a photodiode, to create a photoplethysmogram (PPG) (Philips, 2016). It is designed as a medical device, and it is validated clinically (Koninklijke Philips, 2017).

In comparing these different devices, the focus is placed on the heart rate tracking component, in order to achieve the aim of this study.

Figure 6.7: The Five Smart Devices: A) Vívosmart, B) Philips, C) Pulsoximeter, D) Fitbit-Surge, E) Chest Strap

Many experiments were undertaken as the holder of the device underwent three activity levels: the resting state, the leisurely walking pace and brisk walking. These experiments were started at different times, and the resulting measurements also differed. The results of these experiments are described and discussed as follows:

6.6.1: Experiment-3: in Germany

For this experiment, two devices were used: the Fitbit and Pulsoximeter models. This experiment was carried out on the 21st December 2016 from 10:00 a.m. to 11:00 a.m. For the participants, two activity-types were measured: the state of leisurely walking and the state of rest, as shown in Figure 6.8. In this case, the walking activities took place in the same building in which the state of rest experiment was carried out.

When measuring the differences between these two activity levels, while the maximum heart rate was shown by the Fitbit-Surge as the holder walked at a leisurely pace, the Pulsoximeter appeared to fail in its connection to the laptop at the mid-experiment. Consequently, the results can not be considered as an accurate comparison between these two devices.

Figure 6.8: Fitbit VS Pulsoximeter, 21st of December 2016

6.6.2: Experiment-4: in Germany

In this experiment, the Fitbit, Vívosmart and Pulsoximeter models were used. This experiment was conducted on the 21st December 2016 from 3:15 p.m. to 4:15 p.m. The two activity types observed were the leisurely walking pace and the state of rest, as illustrated in Figure 6.9. The walking activities took place in the same building where the state of rest measurement was carried out. When observing the participant walking at a leisurely pace, the Pulsoximeter began with a reading of 85 bpm, which then dropped to 74 bpm; while the Fitbit-Surge began with a reading of 76 bpm, which then rose to 81 bpm; and the Vívosmart began with a reading of 73 bpm, and then rose to 79 bpm.

In reviewing these results, the readings obtained by the two Smart watch devices were accurate for the participant's leisurely walking pace, whereas the reading from the Pulsoximeter was inconsistent. Furthermore, when the measurements of the participants in a resting state began, the readings on both Smart watches decreased as expected, yet the Pulsoximeter showed a reading that had increased.

Additionally, evidence of this inconsistency was also noticed at 3:50 p.m., when beginning a resting activity: the heart rate readings from the Smart watches saw a decline, whereas the reading on the Pulsoximeter increased. Due to these inaccuracies, it is evident that the Pulsoximeter readings were incorrect and significantly less accurate than those from the Smart watch models.

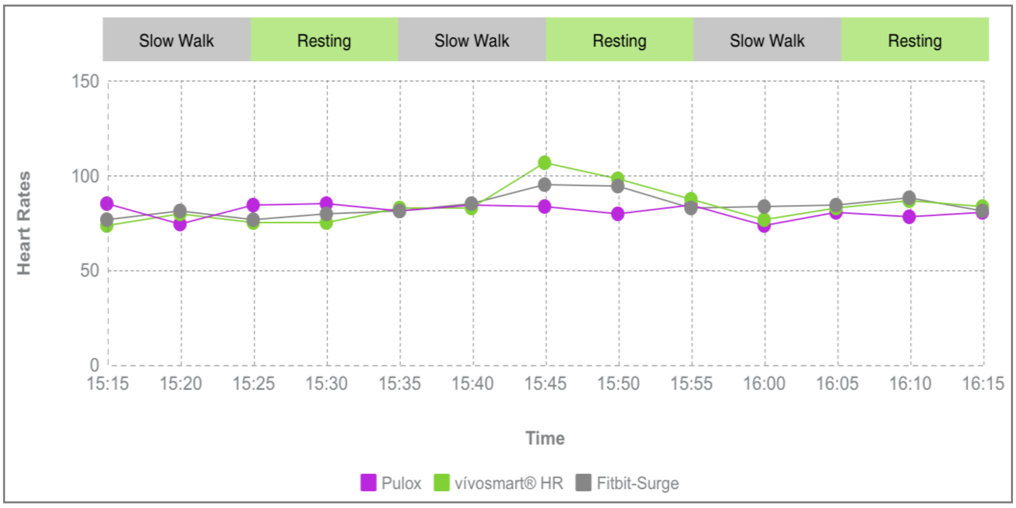


Figure 6.9: Fitbit, Vívosmart, and Pulsoximeter, 21st of December 2016

6.6.3: Experiment-5: in Germany

Unlike the previous devices, now the wearable devices were Vívosmart and Fitbit-Surge, which allowed us to conduct experiments outside, in Stuttgart's city centre. The experiment was conducted on the 21st December 2016 from 5:00 p.m. to 9:00 p.m. In this experiment, the devices were used for leisurely walking pace and state of rest. This experiment is represented in Figure 6.10, and both Smart watches produced roughly the same readings at 81 bpm and 82 bpm However, the readings did change at 9:00 p.m. as the participant reduced activity to a state of rest. Furthermore, during the state of rest, the Vívosmart reading rose to 112 bpm and the reading obtained from the Fitbit-Surge was measured at 92 bpm for this activity level.

Figure 6.10: Vívosmart and Fitbit, 21st of December 2016

6.6.4: Experiment-6: in Germany

This experiment was conducted to compare the readings obtained by the Vívosmart and Pulsoximeter models. This experiment was carried out on the 22nd December 2016 from 10:00 a.m. to 11:00 a.m. In this case, the participants were observed under two activity levels: the leisurely walking pace and the state of rest, which are shown in Figure 6.11. Just as with the former experiments, the walking activities were conducted in the same building in which the resting measurements took place. In this instance, the results clearly indicate the inconsistency of the Pulsoximeter, which was due to a loss of connection.

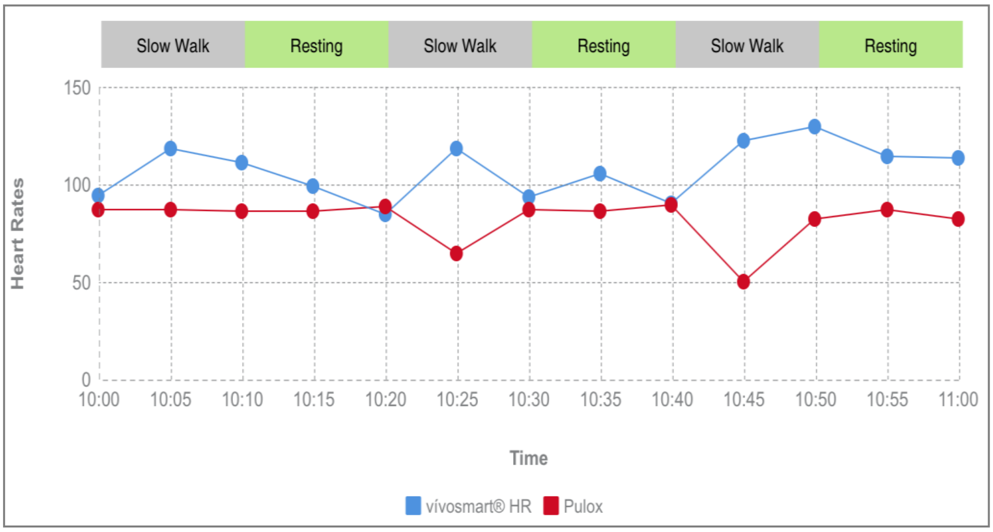


Figure 6.11: Vívosmart and Pulsoximeter, 22nd of December 2016

6.6.5: Experiment-7: in Germany

In this experiment, the four devices, Chest Strap, Fitbit-Surge, Vívosmart and Pulsoximeter, were used on the 22nd December from 11:30 a.m. to 12:30 p.m. The time measured, to see how the data produced by these devices would be represented, was four minutes. In this case, only the activity level of the resting state was observed, in order to identify the differences in time measurement between the four devices.

As illustrated in Figure 6.12, the experiment was conducted inside the building. When beginning the experiment, the four devices began at approximately the same reading. However, we discovered that the Pulsoximeter device again lost its connection to the laptop, resulting in inaccurate readings. Overall, according to the results, we could confirm that the Fitbit-Surge device resulted in acceptable readings.

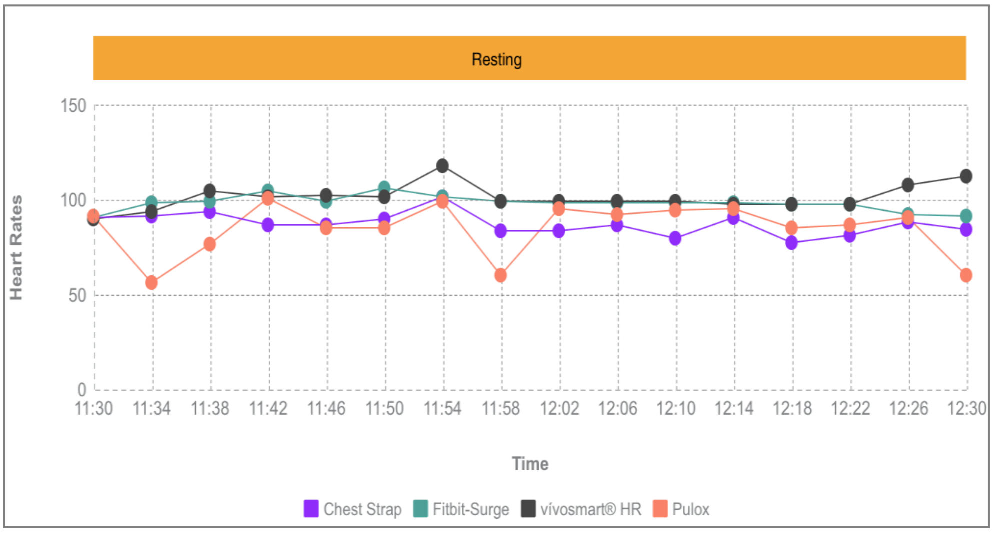


Figure 6.12: Chest Strap, Fitbit, Vívosmart, and Pulsoximeter, 22nd of December

6.6.6: Experiment-8: in Germany

In this experiment, a treadmill was used to simulate slow walking and fast walking. In between each phase, the participant was allowed to rest for five minutes, as shown in Figure 6.13. Each activity was conducted over five-minute durations. This experiment was conducted on the 22nd December 2016 from 2:45 p.m. to 3:20 p.m.

Furthermore, due to technical issues, the data obtained from the Chest Strap could not be retrieved. Consequently, the results from the Chest Strap are omitted from Figure 6.13. As with the previous experiments, this experiment further indicated that the Pulsoximeter provided imprecise heart rates, whereas the readings from the Fitbit-Surge and Vívosmart devices were obtained with a variation at $\pm$ 10%.

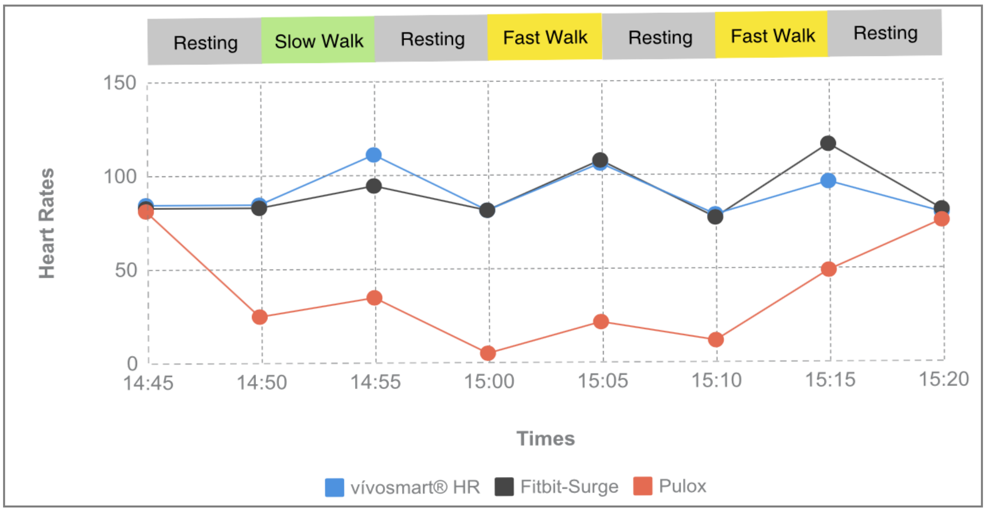


Figure 6.13: Chest Strap, Fitbit, Vívosmart, and Pulsoximeter, 22nd of December

In fact, acquiring a reliable and accurate heart rate is very critical and important, in order to take appropriate action based on these readings. However, some studies indicated that wearable devices such as a Smart watch might possibly give inaccurate readings (Gillinov et al., 2017; Cleveland Clinic, 2017; Ra et al., 2017). This can lead to harmful health issues (Ra et al., 2017). Therefore, we used a Philips Smart watch, which is approved as a clinical Smart watch and tested it against a Fitbit-Surge and chest strap.

6.6.7: Experiment-9: in England

This experiment was conducted on the 31st March from 1:00 a.m. to 7:00 a.m. In this experiment, the participant was observed while asleep. Here, Figure 6.14 below represents the variation of heart rates throughout the experiment. Throughout this entire measured period, the readings were the same, with a variation of $\pm$ 10%.

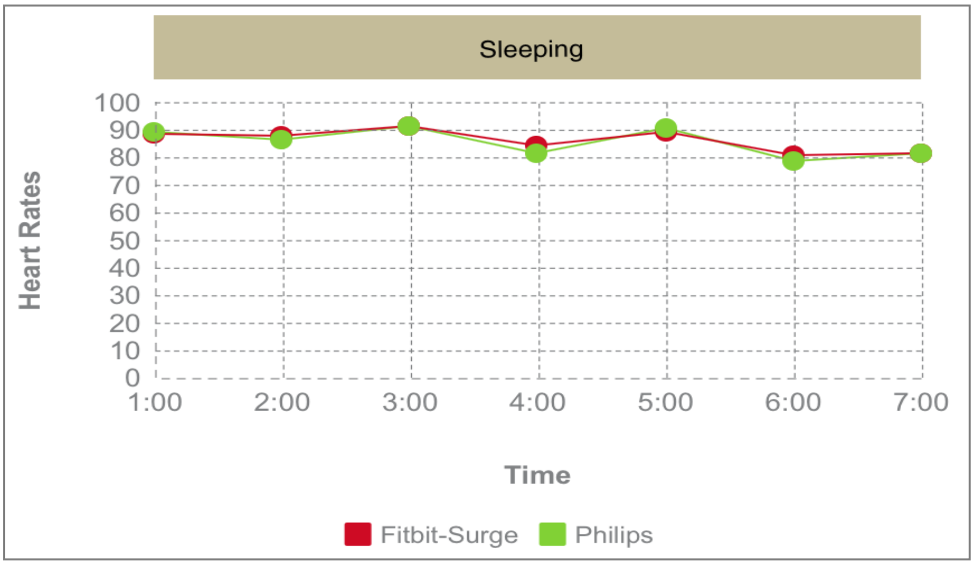


Figure 6.14: Fitbit-Surge and Philips, 31st of March 2016 form 1 a.m. to 7 a.m.

6.6.8: Experiment-10: in England

This experiment in England was undertaken on the 31st March from 9:30 a.m. to 12:00 p.m. In this instance, the experiment attempted to measure the heart-rate readings during the activity of driving. This experiment is illustrated in Figure 6.15. In this case, the readings from both Smart watches were identical. When compared to devices such as the Chest Strap and Pulsoximeter, these results indicate that Smart watches consistently produce roughly the same results.

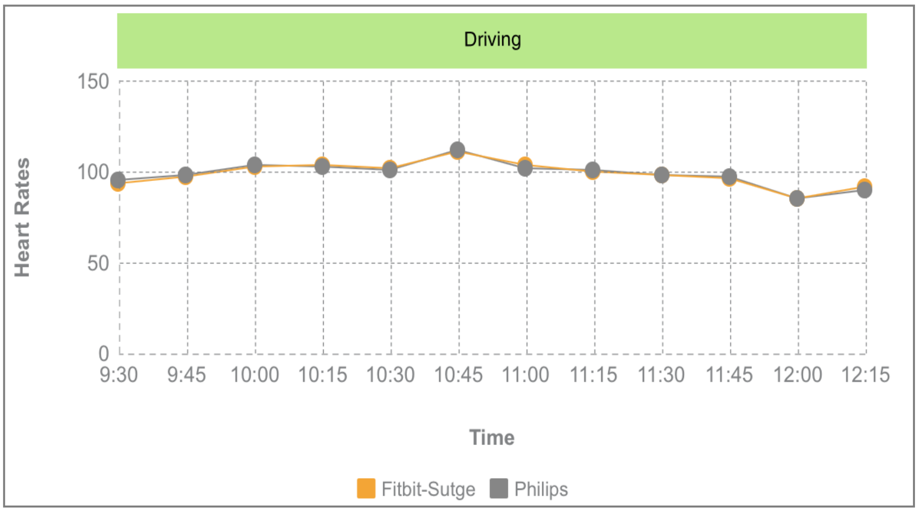


Figure 6.15: Fitbit-Surge and Philips, 31st of March 2016 form 9:30 a.m. to 12:15 p.m.

6.6.9: Experiment-11: in England

This experiment was conducted on the 31st March from 5:50 p.m. to 6:40 p.m. In this experiment, the heart-rate readings where compared from the following states of activity: the leisurely walking pace, the brisk walk, and the state of rest, as illustrated in Figure 6.16. In this experiment, the results further emphasised the capacity of Smart watches to produce accurate results for monitoring heart rates.

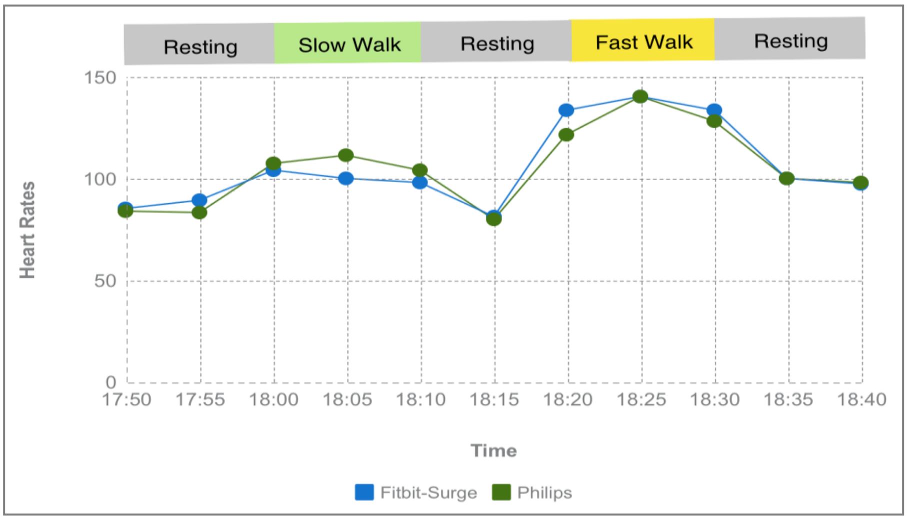


Figure 6.16: Fitbit-Surge and Philips, 31st of March 2016 form 17:50 p.m. to 18:40 p.m.

6.6.10: Experiment-12: in England

This experiment was conducted on the 23rd October from 8:14 p.m. to 8:58 p.m. in order to re-test the accuracy of Smart devices that had been used. In this experiment, the heart-rate readings where compared from the following states of activity: the state of rest (4 minutes), the leisurely walking pace (6 minutes) and the brisk walk (6 minutes), as illustrated in Figure 6.17. This final experiment was conducted in two parts, and the results further emphasised the capacity of Smart watches to produce different results for monitoring heart rates in different cases. The results show that the three activities can be identified as in Figure 6.17.

Figure 6.17: Chest Strap, Fitbit-Surge, and Philips, 23rd of Oct 2016 form 20:14 p.m. to 20:58 p.m.

6.7: Tracking System Experiment

The development of Ambient Assisted Living includes considerable changes in the design of solutions and technologies. Therefore, it is essential to provide users with technologies that can be intelligent and can enable ubiquitous computing and communication. These technologies must be non-invasive, embedded and transparent for users. Therefore, the locations of the user can be determined by Real-Time Locating Systems (Tapia et al., 2012).

Wireless Sensor Networks (WSNs) are used for gathering valuable information for Smart environments. One of the many applications of WSN is the Real-Time Location System (RTLS). RTLS is a system that can be used to offer real-time tracking and positioning of people or objects (Tapia et al., 2011). Considerable studies indicated that there are many wireless technologies that are used for indoor locations. The common wireless technologies are Radio Frequency Identification (RFID), Ultra-Wide Band (UWB), Wireless Fidelity (Wi-Fi), ZigBee (Tapia et al., 2011; Yu et al., 2014; Li et al., 2016) and Bluetooth (Li et al., 2016; Yu et al., 2014).

RFID is one of the most common technologies used for RTLS. It consists of a reader that can transmit signals to be gathered by tags. Each reader is able to cover a certain zone. Once the reader recognises a tag, it can define its zone (Tapia et al., 2012). The cost of reader and active tags is the main issue with this technology, as each of them requires a separate power supply (Abreua et al., 2010).

UWB can estimate an accurate location, since its frequencies run at a high level. However, using this technology for an indoor location has limitations, due to attenuation by objects. There are multipath and reflections issues (Tapia et al., 2012).

Wireless Fidelity (Wi-Fi) can present an advantage compared to *Wireless Local Area* Networks (Wi-Fi), which can work in 2.4GHz and 5.8GHz. It can use a variety of techniques for location, such as fingerprinting or signposting. However, it has some issues, such as high power consumption and interference with current data transmission (Tapia et al., 2012).

ZigBee is '*the wireless language that everyday devices use to connect to one another* (ZigBee Alliance, 2002). The design of ZigBee technology is in accordance with a set of standardisations, which are called 'layers'. ZigBee was preferred because of its efficiency, low power, and simplicity to deploy (Obaid et al., 2014; AlYami et al., 2016; Mu & Han, 2016). ZigBee depends on IEEE 802.15.4 standard, and can be used for many applications, including Smart homes, building automation, motion detectors, healthcare, retail, Smart energy, and telecommunication (ZigBee Alliance, 2002; Wadhwa et al., 2016). ZigBee can be utilised to comprehend issues and enhance individuals' lives (Yuan et al., 2016). The ZigBee features and standards are better compared to aforementioned technologies (García et al., 2012; Zato et al., 2013). However, the battery consumption is high (Bouchard et al., 2016).

Beacons are Bluetooth Low Energy (BLE) that are low cost. They have a small size and their battery can work for seven years. They are easy to install and to attach to walls. In fact, this is considered as a potential selection to be used for AAL (Bouchard et al., 2016). Despite the advantages of Bluetooth beacons that are provided, non-transparent, and possibly interfering connections are the major drawbacks (Abreua et al., 2010).

Determining the location of an elderly person can help us to discover if he/she is active or not, to know if he/she enters a restricted area to be monitored, such as being in a kitchen for cooking and to determine his/her location if an emergency arises, so as to prevent hazards occurring, etc.

For the purpose of this research, ZigBee and Bluetooth beacon technologies were used in order to determine the location of an elderly person in his/her home. Therefore, two experiments were conducted using Bluetooth beacons and ZigBee technology to monitor and track the indoor location of an elderly person.

6.7.1: Tracking Location Using Bluetooth Beacons

The aim of this experiment was to monitor the location of the researcher in his home. Beacons with Bluetooth Low Energy (Figure 6.18) were used in this experiment. The number of beacons used was six.

Figure 6.18: Bluetooth Beacons Devices

An app was installed on the author’s phone, and the phone was connected with the Beacons via Bluetooth. The experiment started with mapping two indoor locations, which were in one room on the first floor (Figure 6.19).

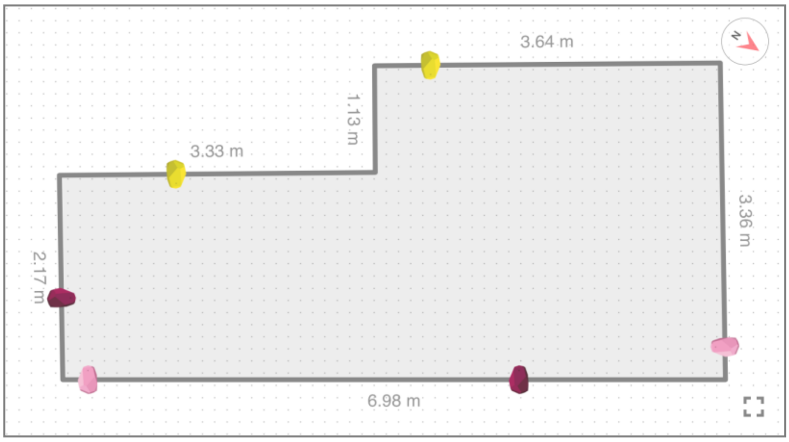


Figure 6.19: Mapping the Indoor Location for The First Room

The second room was on the second floor, as illustrated in Figure 6.20. The Indoor app was used, and then Beacons were attached to the walls on each side.

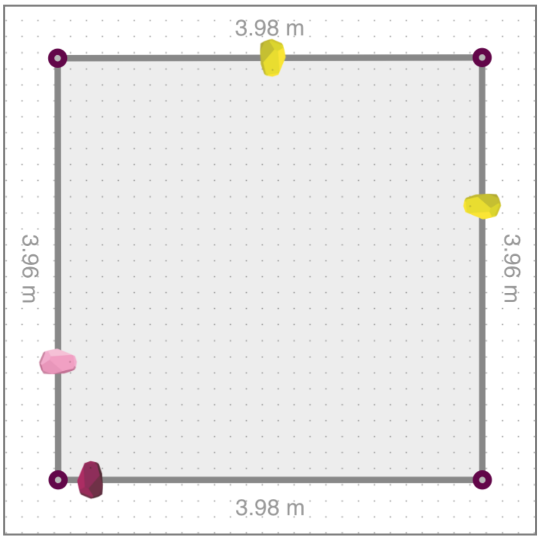


Figure 6.20: Mapping the Indoor Location for The Second Room

The phone receives the beacon's signal and the distance is estimated by measuring received signal strength. The approximate location is uploaded to the Cloud, which allows us to determine the location of the person.

6.7.2: Tracking Location Using ZigBee Technology

The aim of this experiment was to monitor the person in his/her home, using a ZigBee by n-Core Polaris system. The system was installed in the researcher's home.

Based on the n-Core platform (which features an outstanding level of automation, integration, flexibility and precision), the n-Core Polaris can be considered an innovative real-time locating system, for both outdoor and indoor applications. By taking advantage of the same n-Core platform, Core Polaris is able to access the existing advanced functionality of the n-Core Application Programming Interface and the n-Core Sirius devices (Tapia et al., 2012).

➢ Components of n-Core Polaris

For the n-Core Polaris system, its wireless infrastructure is comprised of ZigBee nodes (e.g., readers, sensor controllers and tags). These nodes are lettered n-Core Sirius A-D. Additionally, each node comes in versions at frequencies of 868/915MHz and 2.4GHz, each with a USB to either provide power or charge the batteries. Additionally, configurations of the parameters, and device firmware's updates can also be delivered using the USB port, using a specially designed computer based application (Tapia et al., 2012). Figure 6.21 shows n-Core components.

Figure 6.21: n-Core Components

➢ Usage of n-Core Sirius

For use in one case, the n-Core Sirius B devices are designed for use with an internal battery, and two general-purpose buttons on the devices are included. For another use case, however, the n-Core Sirius D devices are intended as fixed ZigBee routers, where a USB adaptor is used to access the power supply. Furthermore, in the case of the n-Core Polaris RLTS, the tag function is fulfilled by the n-Core Sirius B devices, whereas the reader function is fulfilled by n-Core Sirius D devices. By defining these functions, the location of users and objects carrying the n-Core Sirius B devices can be identified; whereas, for tag detection, n-Core Sirius D devices are placed on walls and ceilings. Last of all, multiple communication ports (I2C and ADC; GPIO; and UART via DB-9 RS-232 or USB) are incorporated by Sirius A devices, so that distinct devices can be connected, including almost every form of actuator and sensor (Tapia et al., 2012).

➢ Architecture of RTLS

The basic architecture of the Real-Time-Locating System in n-Core Polaris is represented in Figure 6.22. For this system, its kernel comprises a computer attached to a ZigBee network that the n-Core devices collectively create. Firstly, as part of this structure, an n-Core Sirius D is connected to the computer via USB, which functions as a coordinator for the ZigBee network. Then, a web server module is run by the computer, to utilise a set of dynamic libraries that constitute the n-Core API (the Application-Programming-Interface). Additionally, the functionalities of the ZigBee network are facilitated by this API, and the web module facilitates the set of innovative location techniques provided by the n-core API.

As part of this structure, information is delivered, on the one hand, to the coordinator node by the n-Core Sirius D, which acts as reader; whereas, on the other hand, the computer functions as a web service, generating location-based information that a wide range of client interfaces can use. Furthermore, as well as facilitating these functions, a remote database can also be accessed by the web server module, in order to retrieve user information and collect a set of data on device information history. This can include location tracking and alerts (Tapia et al., 2012).

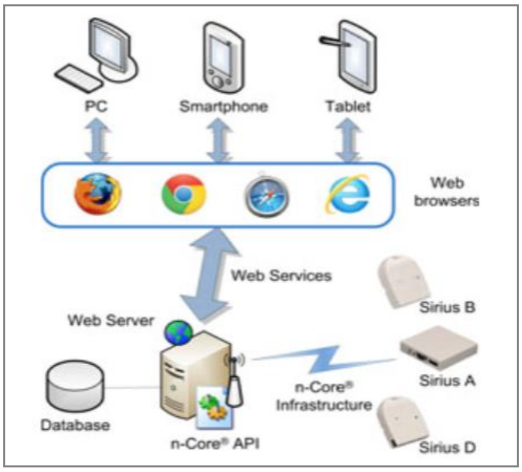


Figure 6.22: Architecture of RTLS

➢ Operation of RTLS

The process of doing this experiment is illustrated in Figure 6.23 and includes the following steps:

Firstly, each object or user carries an n-core Sirius B acting as a tag, which is located by the system. Each tag continually transmits a data frame, which has its unique system identifier, as well as other information. For the periods when the devices are not seeing a tag, in order to ensure a reduction in power consumption, they are maintained in sleep mode. This allows the battery charges to last up to several months of usage within these system parameters (transmission power and broadcast period).

Secondly, n-Core Sirius D devices are used to act as readers, and are attached to the walls and ceiling. Then, the frames transmitted by each tag are received by the readers that are in close proximity. Using this approach, the reader devices store within their memory a table containing an entry for each tag detected. In each entry there is the tag identifier, in addition to the LQI (Link-Quality-Indicator) and the RSSI (Received-Signal-Strength-Indication) gathered from the reception of the broadcast frame.

Thirdly**,** this table is continually sent by each reader to the coordinator node to which the computer is connected. In this way, each table received from each reader is sent to the computer via USB. By using these information tables of detection, a set of locating techniques are used by the n-Core API, so that the position of each tag can be predicted. Among such techniques are: trilateration, signpost, and the innovative technique of location identification based on the fuzzy logic system.

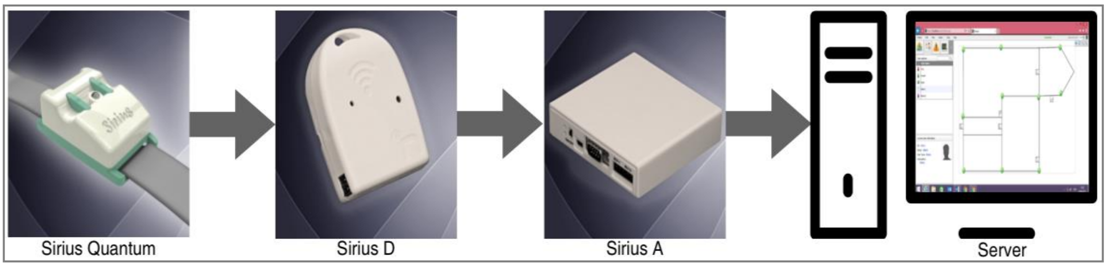


Figure 6.23: Operation of RTLS

Finally, the location data is then provided by the web server module to the remote client interfaces over SOAP (Simple-Object-Access-Protocol), in the form of the web service HTTP (Hypertext-Transfer-Protocol). The web client interface is designed to be intuitive, easy-to-use and simple, and the map used in this experiment is presented in Figure 6.24, which demonstrates the map of the home that was used for this experiment. By using these different interfaces, the administrator can monitor in real-time the position of all objects and of all users that are present on the system. Moreover, the system can be queried by the administrator, to track a user's location whenever necessary, producing statistics such as the most frequent area visited.

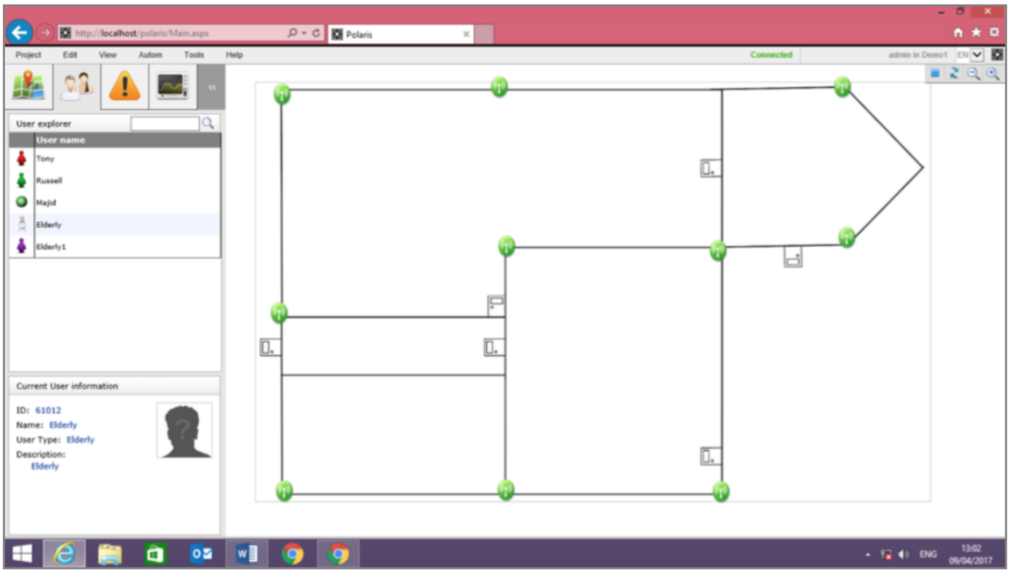


Figure 6.24: Web Client Interface of the n-Core Polaris System

In this experiment, three tags were used to represent the different locations of the person. The person moves and puts the tag in each location he visits in order to be identified by the system as illustrated in Figure 6.25 and Figure 6.26.

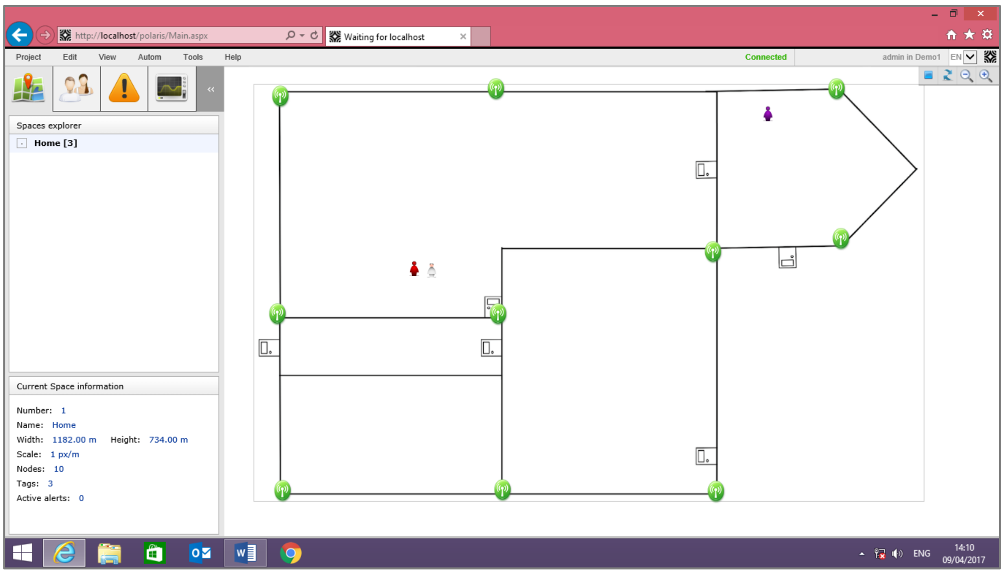


Figure 6.25: The First Identification of Location of a Person

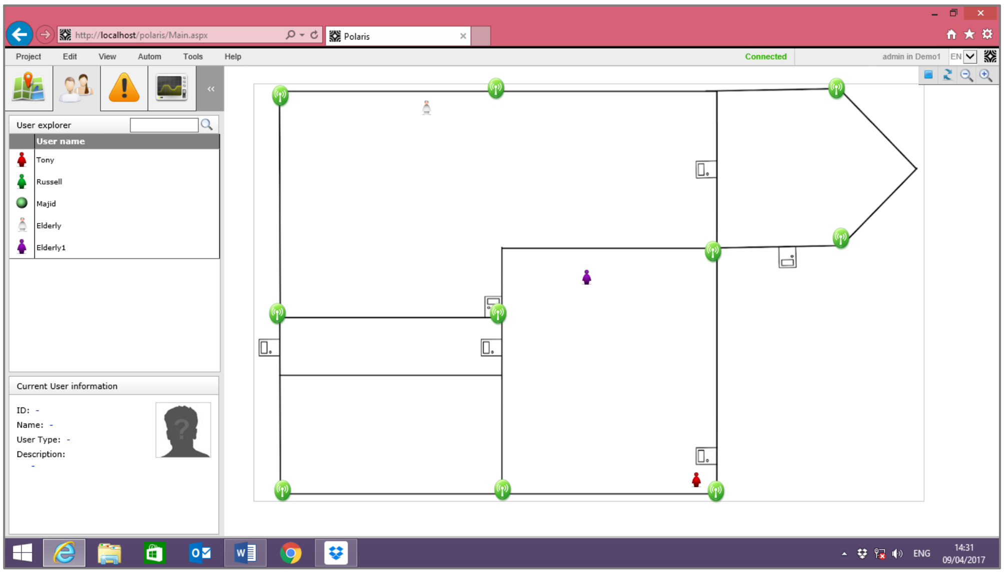


Figure 6.26: The Second Identification of Location of a Person

➢ Other Features

One of the general-purpose buttons of the n-Core Sirius B devices can also be used by the user to send a system alert. Alerts can also be sent from the system by the administrator to one or a set of users, and their reception can be confirmed with other buttons. Additionally, features relating to location are not the only functionality that the system facilitates, as the functionality of automation and scheduling are also present. Therefore, the system can be integrated easily with a wide range of actuators and sensors, by using the variety of communication ports that the n-Core Sirius devices include. Overall, by using the automation engine that can be provided by the n-Core API, automation tasks, as well as real-time environment sensor monitoring, are possible under the n-Core Polaris system (Tapia et al., 2012).

Administrators can also define restricted locations according to the permissions allowed to a user. In the event that such a user enters an area not granted to him/her, a system alert is generated by the system and is delivered via the client interfaces to the administrator. Furthermore, as well producing such notifications, alerts are also registered on the database so that an administrator is able to check whether any of these permissions have been violated by a user in the past (Tapia et al., 2012).

6.8: Surveillance Camera

The aim of this experiment is to monitor a person in his/her home using a live camera. In Chapter 5, the results indicated that 53% of elderly people disagreed with being monitored by a camera, compared with 27% who agreed. However, 66% of elderly people would prefer to switch on a camera in case of emergency. Therefore, this experiment was conducted to ensure that the camera technology could be used to monitor elderly people in their home when an emergency case occurs, so as to prevent medical issues from happening.

- **Motivation**

Falls are considered a major concern among the elderly people of Saudi Arabia (Al Saif et al., 2012). Globally, falls can affect elderly people's lives, since they cause medical and social consequences (Dubois & Charpillet, 2013; Botia et al., 2012).

Hence, many cameras can be installed in the elderly person's home, to assist in monitoring him/her, and many elderly people might subscribe to the system we propose. However, it is difficult to recognise which camera to turn on when an emergency case occurs for an elderly person. Thus, in the tracking system used to determine the location of an elderly person at home, and taking into consideration personal privacy, a camera could be identified, and it could be used for alive conversation with the elderly person, if they agreed.

- **Experiment**

Two cameras were installed at the researcher's home, as shown in Figure 6.27. They could be connected to the router via a cable or wirelessly. They were easy to install and access. An app was installed on the author's phone, which enabled to easily access it from anywhere and anytime, via a mobile phone. The cameras can see at night up to 15 feet away.

Figure 6.27: Camera Used

Each camera and its app allowed the object to be viewed; which, in this case, was the author at home, as illustrated in Figure 6.28.

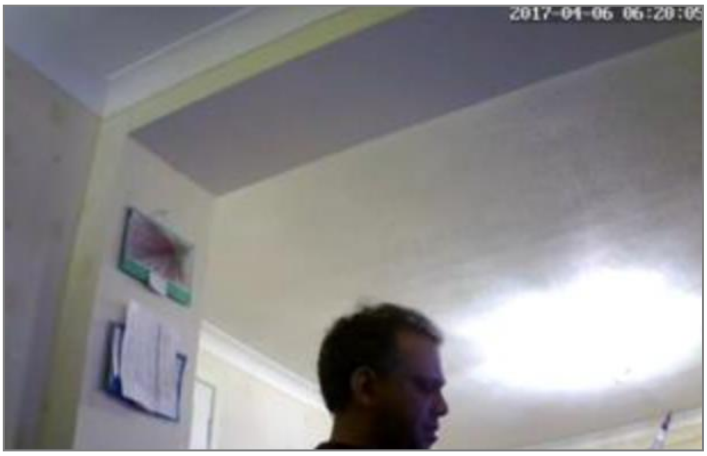


Figure 6.28: Viewing Objects

6.9: Conclusion

Currently, one of the most prevalent threats to elderly people is heart disease. The prospect of using wearable devices to anticipate heart irregularities and suggest preventative measures appears promising. The systems currently in use do not take action when an abnormal heart event occurs, and only display the data. A knowledge-based system (KBS) could be used to generate an intelligent action within a Smart watch. This study points towards Smart watches as the most reliable solution, compared to the other devices tested. A series of experiments carried out in the UK, the KSA and Germany, showed that the Smart watches included in the study produced consistent readings. From the results of these experiments, the devices included can be ranked from 1 (best) to 5 (worst) according to their reliability: (1) Philips, (2) Fitbit-Surge, (3) Vívosmart, (4) Chest Strap and (5) Pulsoximeter.

Overall, the first four devices demonstrated consistent readings throughout the experiments, with a variation of ± 10%. However, in some cases, these Smart watches could provide inaccurate data, which could lead to medical issues. The least reliable data was produced by the Pulsoximeter device, due to loss of connection. Both the Chest Strap and Pulsoximeter have limited scope in terms of the monitoring of elderly people within their home environment but are useful for comparison and calibration purposes. Experimentations using the Real-Time-Locating System in the n-Core Polaris and cameras were designed and implemented, proving that, when required, each camera can be identified, and it could be used for a live conversation with an elderly person within their home environment, if they agreed. Therefore, the experiments covered in this chapter have determined the characteristics of systems that allow a combination of the detection of the heart rate and location of an aged person with communicating with him/her and/or summoning advice and help.

Chapter 7: The Developed Model

7.1: Introduction

Chapter 6 discussed the definition of heart rate (HR), and the types of technologies that might be used to monitor elderly people at home. Experiments were undertaken using Smart watches, chest straps, Bluetooth beacons, ZigBee and cameras.

In this chapter, an in-depth survey and analysis of 20 existing AAL projects and applications (from 2012 to 2017) were reviewed, in terms of operational layers and concepts. This information was used in a first-principle design, in order to produce a seven-layer conceptual model, based on the holistic framework factors that were outlined in Chapter 5.

The aim was to provide a proactive monitoring system, using Smart watches to support elderly Saudi Arabians to live at home. This model was modified from the experimental results as outlined in Chapter 6 where the visualisation layer was integrated with the proactive control centre layer, to produce a six-layer overall model. This included the following services: calling; texting; alerting and emailing the elderly; contacting families; contacting relatives or carers; visualising daily activities; early report to families, relatives, carers etc; dispatching a doctor or a nurse and calling an ambulance or the police.

7.2: AAL and Development Applications

Peetoom et al. (2014), stated that Celler (1995) demonstrated the first monitoring technology, which monitored elderly people's health status remotely. Furthermore, Pannurat et al. (2014) clarified that the first fall-monitoring system was designed in the early 1970s, and it used a button that is pressed to send an alert message.

Considerable research has clarified the needs and reasons for using AAL technologies to monitor elderly people, in order to prevent risks and assist ageing in place (J.Bellmunt et al., 2016).

These needs and reasons can be identified as: fall-detection, presence detection, sleep monitoring, physiological parameter tracking (heart and breathing rates and gait), physical cleanliness, routine action monitoring (Activity of Daily Living), Parkinson's disease, diabetes, Alzheimer's disease, posture detection, location tracking, health status, overweighing, medical guidance, treatment prescription, and economic reasons (Bourouis et al., 2011; Lv et al., 2010; Susanne & Labonnote, 2015; Tsukiyama, 2015; Huq et al., 2015; Ni et al., 2015b; Darwish & Hassanien, 2011; Pouke & Häkkilä, 2013).

Therefore, significant research has been undertaken to study, design, develop and innovate AAL solutions to monitor elderly people, and help to support their independent living. Some of the most proposed and applied monitoring solutions have used the following technologies:

- In-home passive infrared motion sensors
- Body-worn sensors
- Video monitoring or optical sensors
- Ultrasound passive system
- Pressure sensors
- Radio frequency passive systems
- Electric sensing
- Sound recognition or audio sensors
- Biological and environmental sensors
- Ambient and environmental sensors
- Radio Frequency Identification (RFID) sensors
- ZigBee.

(Peetoom et al., 2014; Arshad et al., 2015; Darwish & Hassanien, 2011; Susanne & Labonnote, 2015).

Ambient Assisted Living (AAL) is a technological innovation that is intended to improve the life quality of the elderly, and has the capability to support their requirements in their later years, through the application of technology (Ansari et al., 2014). It is developed through consideration of automation of their homes and through assistive domesticity. It provides people in this age group (elderly) with assistance in carrying out their daily activities, prolonging their life expectancy, and improving their social life and communication (Blasco et al., 2014).

According to Altamimi (2016), given the projected increase in the elder population, AAL is becoming an important health consideration for the KSA. However, its application will impose an increasing financial expenditure on the Ministry of Health in meeting the needs of the elderly (Ansari et al., 2015).

It has been found that the elderly population is prone to vulnerabilities, especially in healthcare, while research has shown that AAL technology, with close monitoring, will ensure improved quality of life for the elderly, delivering the crucial services that have a transformative benefit in their lives. However, in the approach presented above there is a gap in terms of monitoring the effectiveness of AAL, and the current study intends to address this in an effective way (Karlin et al., 2016).

7.3: Methodology of AAL Technology Applications

A literature review was conducted to identify the layers or concepts that are used to develop a model, framework, architecture and platform for monitoring people in their homes or in any other environments. Saudi Digital Library and Staffordshire University Library were used to retrieve articles from different databases (e.g.,, SCOPUS, IEEE Xplore, PubMed, ProQuest, Science Direct, ACM Digital Library, SpringerLink, Wiley Online Library). Google and Google Scholar were also searched, together with reports and working papers. Websites were also investigated. A cross-referencing method was used and 20-selected studies for this research are presented in Table 7.1.

Table 7.1: The Selected Studies

#	Authors	Population	Services
1	(Lara et al., 2012)	General	Detecting, Visualising
2	(Jin et al., 2012)	Dementia	Sending an Alarm
3	(Han et al., 2012).	Elderly	Reporting, Visualising
4	(Kirbas & Bayilmis, 2012)	Elderly or ill People	Alerting, Visualising
5	(Chatterjee et al., 2013).	Older adults	Message
6	(Suryadevara et al., 2013)	Elderly	Message, Visualising
7	(Alumona et al., 2014)	Patient and Elderly	Advices via Internet
8	(Mukherjee & Dolui, 2014)	Patient	Sending an Alarm. Making an Appointment
9	(Skubic et al., 2015)	Seniors	Alerting by email
10	(Jimenez & Torres, 2015)	Elderly People	Alerting, Visualising
11	(Kakria et al., 2015)	Aging Population	Alarming Messages, Visualising
12	(Khoi et al., 2015)	Ageing Population	Visualising
13	(Nachabe et al., 2016)	Aging Population	Notification services
14	(Ni et al., 2016)	Elderly	Visualising
15	(Pathinarupothi et al., 2016)	Patient	Alerting, Visualising
16	(J.Bellmunt et al., 2016)	Aging people	detecting Activities
17	(Gómez et al., 2016)	Patient	Notifications
18	(Chuang et al., 2016)	Senior Citizens	Alerting, Visualising
19	(Miramontes et al., 2017)	Elderly and Ill Patients	Alerting, Reporting
20	(Aihua et al., 2017)	Elderly People	Alarming, Visualising

7.3.1: Overview of the Selected Studies

A number of research developments accomplished in the AAL field have enhanced the technological services available to elderly people. Many technologies and projects have been designed and deployed as Smart environments that can assist elderly people. Some of those are outlined as follow:

1. Centinela is a human activity recognition system based on acceleration and vital sign data. It monitors five activities, which are walking, running, sitting, ascending, and descending. The system consists of a portable and unobtrusive real-time data collection platform. It uses sensing devices and a mobile phone. The sensing device connects via Bluetooth with a phone, and then data are sent to the application server through the Internet as illustrated in Figure 7.1 (Lara et al., 2012).

This system classifies the users' activities, visualises the measurements, and labels each measurement according to the five activities. Then the labelled data is stored in the application server.

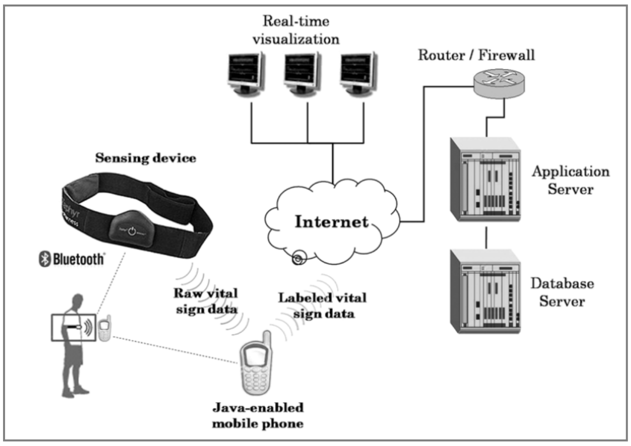


Figure 7.1: System Architecture
Source: (Lara et al., 2012)

2. Jin et al. (2012) proposed a monitoring system that relies on different sensors to detect risky situations for the elderly. It is composed of four layers, which are sensor, client, repository and infrastructure. For this system, an elderly person carries a Smart phone or wears a fall detector. The Smart phone sends the location and personal data via Bluetooth to an agent. If a critical event occurs, it informs the caregiver as illustrated in Figure 7.2. It is used to determine whether the elderly person is at risk or not. It can send an alarm to a caregiver when identifying a risk.

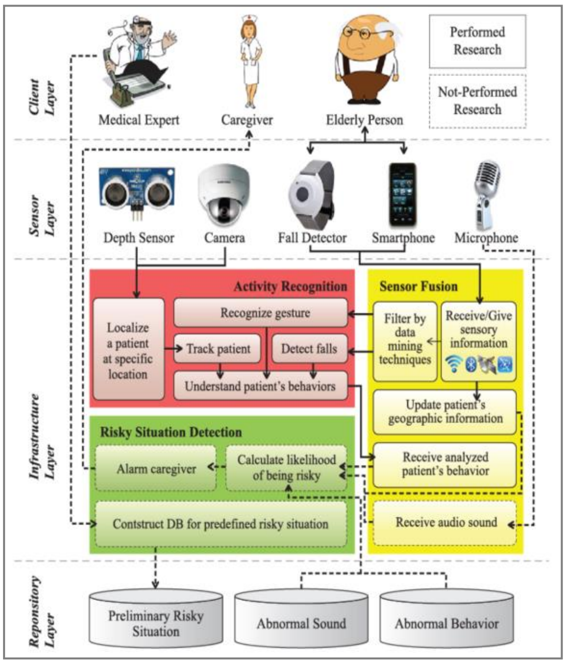


Figure 7.2: Architecture of Surveillance System
Source: Jin et al. (2012)

3. A healthcare framework was presented, to predict the risk of lifestyle disease. It uses long-term activity monitoring and creates the activity pattern for each day. It is composed of three layers: activity classification, activity pattern generation, disease inferring and application. The clinician and caregiver can monitor the activity database remotely, via a web-based healthcare application. By monitoring users' activities in the long term, the system can predict lifestyle disease, and then define the risk of a lifestyle disease, as shown in Figure 7.3 (Han et al., 2012).

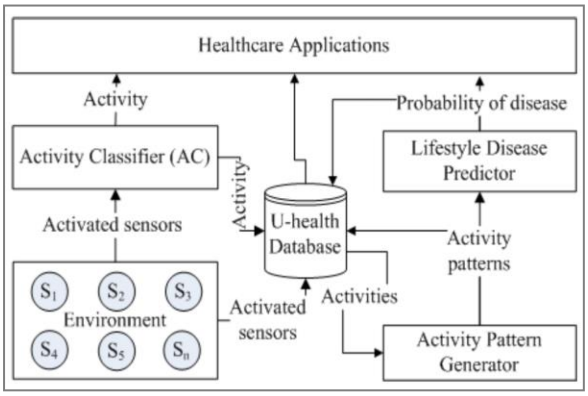


Figure 7.3: Proposed Healthcare Framework
Source: (Han et al., 2012)

4. System Architecture was proposed as a web-based interface to allow doctors or caregivers to monitor patients. It consisted of three layers, which are a WBASN, network coordinator, and a medical centre. WBASN processes the data that comes from sensors. The network coordinator sends the data collection to the medical centre, which can then be monitored by doctors or caregivers. The doctors or caregivers can analyse these data, and the system sends an alert to the medical care staff to interfere. It uses MATLAB to program the system (Kirbas & Bayilmis, 2012), and Figure 7.4 shows the proposed system architecture. The system cannot predict what might happen to patients, nor does it mention what services can be provided to patients. It seems to be a project that was proposed for a hospital.

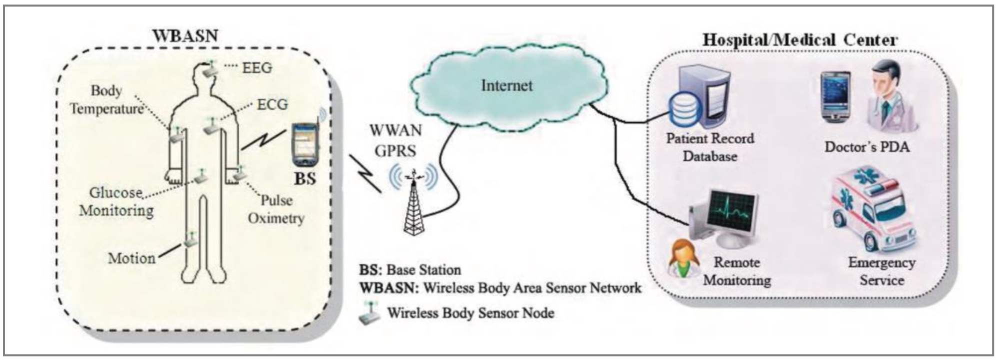


Figure 7.4: The Proposed System Architecture
Source: (Kirbas & Bayilmis, 2012)

5. An in-home activity monitoring system was established to monitor elderly people with diabetes. It uses sensors and body wearable sensors, which use a laptop via USB to upload data to the Cloud. The client receives a daily text message and a weekly health newsletter (Chatterjee et al., 2013). This system can be considered to be a reminder that just reminds a patient, and no actions can be taken when unusual events occur.

6. Suryadevara et al. (2013) designed an AAL framework for a Smart Home Monitoring System, as illustrated in Figure 7.5. It is composed of three modules: instrumentation, communication technology, and data processing. It uses AAL Middleware to connect these components. It captures data from sensors and uploads them to a website. It can send an alert message to the caregiver if changes happen in the elderly person's daily routine. It is a website that helps caregivers to visualise an inhabitant's data.

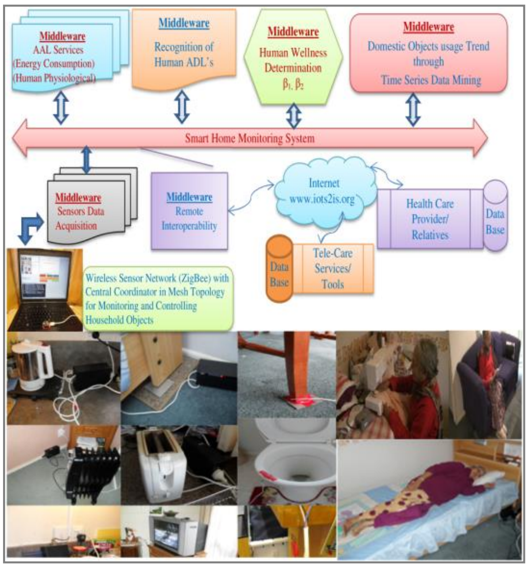


Figure 7.5: AAL Framework for Smart Home Monitoring System
Source: (Suryadevara et al., 2013)

7. Alumona et al. (2014) proposed a remote patient monitoring system that consists of three layers: wireless body area network (WBAN), personal server using Intelligent Personal Digital Assistant (IPDA), and a medical server for healthcare monitoring. Wearable sensors are attached to the patient's body to closely monitor any changes in the patient's vital signs. It provides a real-time response to retain the best health position. The data are collected from WBAN and are processed. Then, the crucial data are prioritised and forwarded to the medical server. Some treatment advice can be sent to the patient. If there is an emergency, the doctor takes action.

Figure 7.6 shows the architecture of the system.

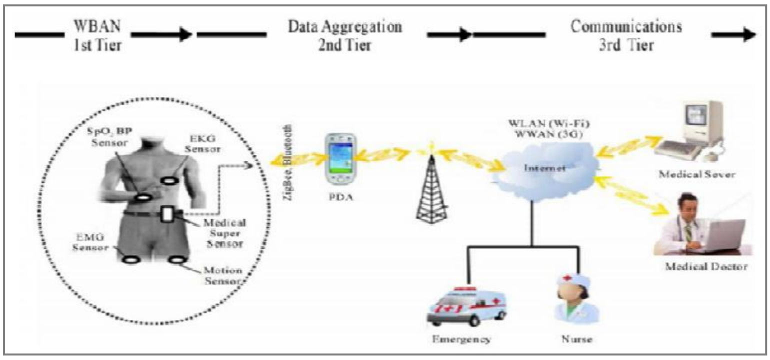


Figure 7.6: Architecture of Wearable Sensors for Remote Healthcare Monitoring System
Source*:* (Alumona et al., 2014)

8. An e-health system was designed to monitor patients' health by using Smart devices and wireless sensor networks. It was designed for rural hospitals in India that might not have all the necessary equipment to monitor a person at home and in a hospital. The system is divided into three layers as shown in Figure 7.7. The perception layer is in charge of gathering data from medical sensors and environmental sensors, which are in the patient's body or around it. Middleware and APIs constitute the second layer, which stores the data in a cloud and transmits them to the third layer. The E-Health Application and service layer provides patients with subscriptions and suggestions, based on the acquired data. An alarm can be delivered to doctors and caregivers, with the level of emergency detected. It allows patients to make an appointment and to choose the doctors they need (Mukherjee & Dolui, 2014). This system provides prescriptions and advice to patients, and alarms to doctors and caregivers. It is analysed by attendees in the Care Centre.

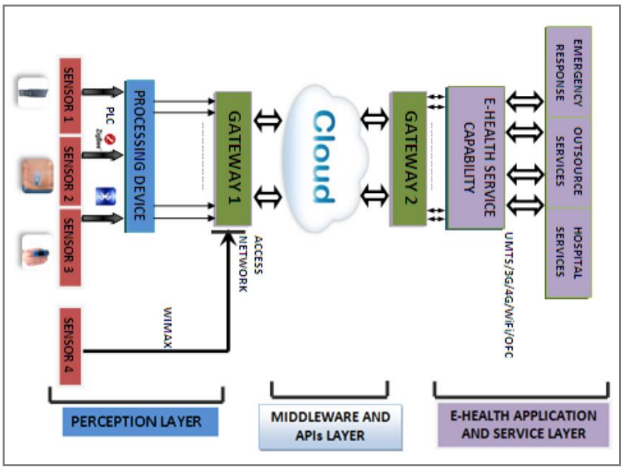


Figure 7.7: e-Health Monitoring Architecture
Source: (Mukherjee & Dolui, 2014)

9. One study outlined a home sensor monitoring system for discovering early changes in health conditions for older people. Sensors are installed in the home, and the data are stored on a secure server. The data are analysed and observed daily. When changes in the user's data patterns occur, an alert email is then sent to the clinicians. This email allows clinicians to log in to a portal, to visualise the patterns of the person, as shown in Figure 7.8 (Skubic et al., 2015).

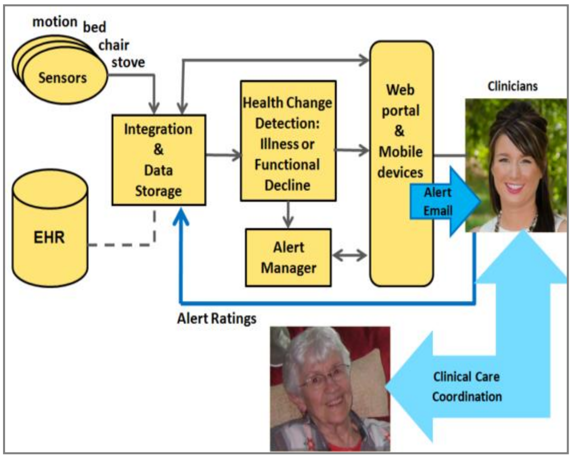


Figure 7.8: Integrated Sensor Network with Health Alerts and Ratings on Clinical Relevance
Source: (Skubic et al., 2015)

10. Jimenez & Torres (2015) designed an IoT-aware healthcare monitoring system, which uses sensors to collect data such as temperature, pressure, and gyroscope, and accelerometer readings. The data are transferred to a phone app via Bluetooth. A doctor can monitor more than one patient at the same time. Doctors and a patient's relatives can be alerted when the patient is shown to be facing health problems. The system is illustrated in Figure 7.9.

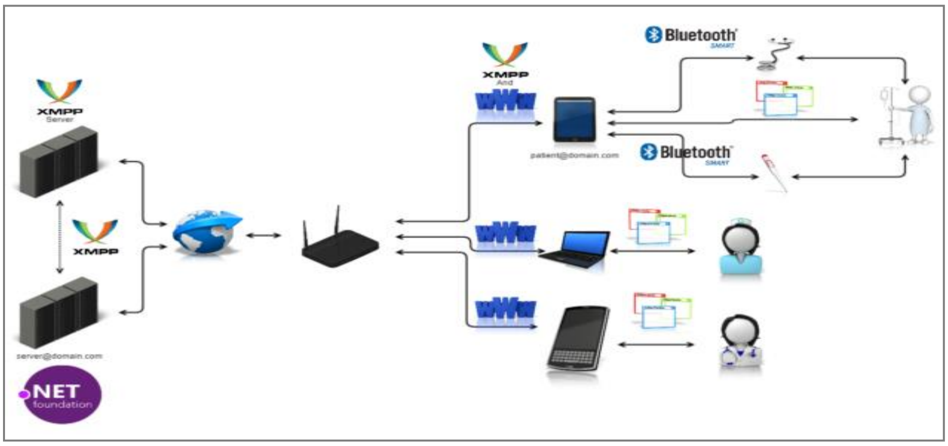


Figure 7.9: System Architecture,
Source: (Jimenez & Torres, 2015)

11. System Architecture was also developed to remotely monitor cardiac patients through wearable sensors and Smart phones. It is composed of the three layers, which are wearable biosensors, an Android device and a web portal. The first layer collects the data from patients, and then sends them to the second layer, which is a Smart phone, via Bluetooth. The Smart phone connects to the third layer via a wireless connection and transfers the data to the portal.

Alarm Messaging is built into the system if abnormal events occur, as shown in Figure 7.10. The doctors are allowed to analyse the data and to diagnose the condition of the patient. This is application architecture that allows doctors to distinguish the status of patients. The system sends an alarm message when abnormalities occur (Kakria et al., 2015).

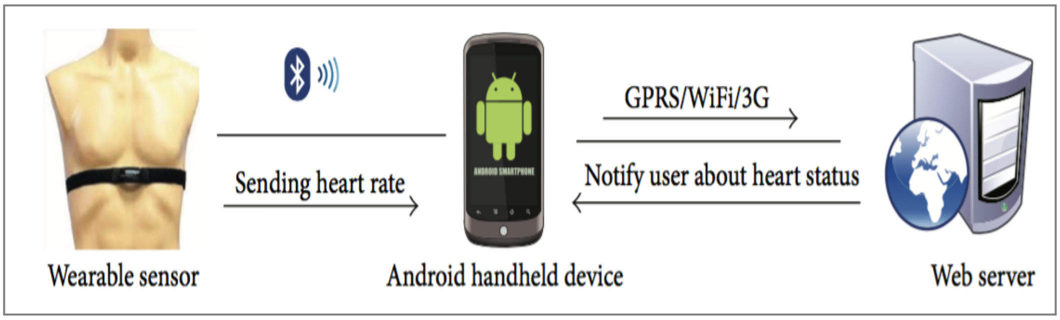


Figure 7.10: The Proposed System Architecture
Source: (Kakria et al., 2015)

12. IReHMo is an architecture that was designed by (Khoi et al., 2015). It consists of five tiers, which can be identified as: sensing tier, home gateway, network infrastructure, cloud computing and application tier, as illustrated in Figure 7.11. The Sensing tier is responsible for collecting data and sending them to the second tier, which is the home gateway for processing.

The third tier is the network infrastructure, which allows the data to be sent to the monitoring system. Further processing can be done in the cloud tier and transferred to produce meaningful knowledge. Data can be remotely monitored by the application tier, which responds to emergency events that can be analysed. This study does not indicate what services, if any, can be delivered to users.

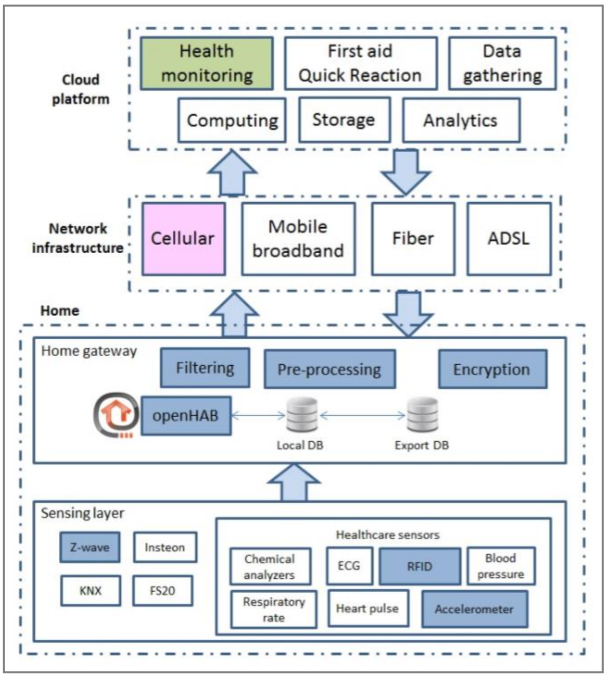


Figure 7.11: The proposed IReHMo Architecture
Source: (Khoi et al., 2015)

13. OntoSmart is a health Smart care home system that attaches sensors to the patient's body for vital signals' monitoring. It uses a local server and actuators/ sensors that relates to home appliances and ambient parameters. This system has two apps, for initialising the system and displaying the monitoring values, and for remote patient monitoring, as illustrated in Figure 7.12. Notifications can be sent if abnormal heart rate or fall detection occurs (Nachabe et al., 2016).

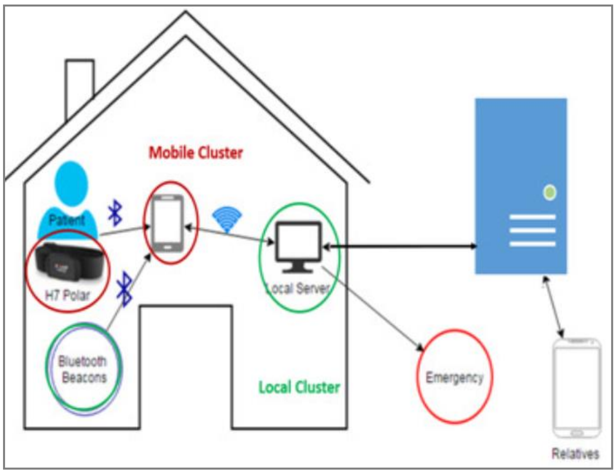


Figure 7.12: OntoSmart General Architecture,
Source: (Nachabe et al., 2016)

14. A three-layered architecture for monitoring activities of daily life in Smart homes was developed by (Ni et al., 2016). The first layer consists of physical hardware and network components. The second layer consists of data pre-processing, context ontology framework and context reasoned. Finally, the application layer allows caregivers/experts to view the elderly person's health status, and give support when it is needed, as in Figure 7.13 (Ni et al., 2016).

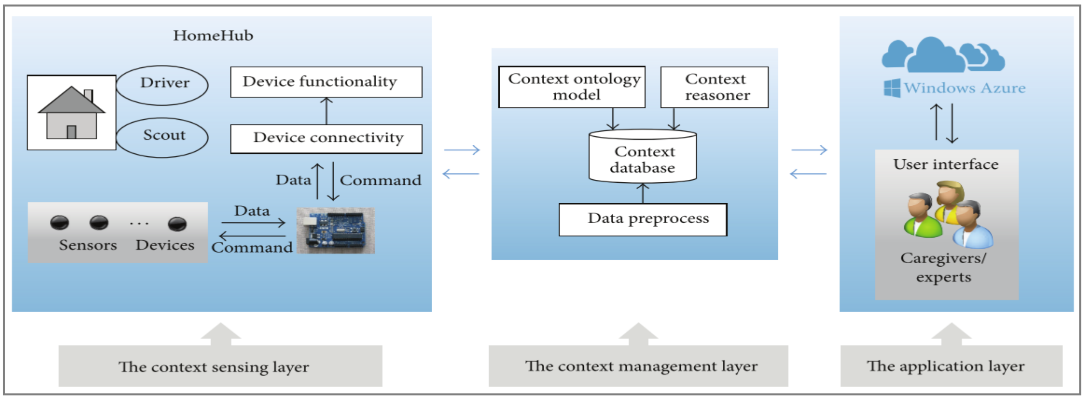


Figure 7.13: The Three-layered Architecture Overview
Source: (Ni et al., 2016)

15. Multi-Layer System Architecture for remote health monitoring comprises six layers. The patient is the core context for this system. He/she can be at home, in a hospital or outdoors. Sensors are attached to the patient's body. The Routing Decision layer stores, analyses and transmits data to the IoT device. The Local PAS is responsible for summarising and classifying the severity of data. The Complex PAS layer is a high-level layer that is processing data that cannot be processed by the local PAS layer.

The application layer is a tool for the clinical staff, involved in visualising, monitoring and intervening. Finally, health service personnel gather data from different applications and allow clinical staff to visualise them. The whole system is shown in Figure 7.14. This developed architecture provides clinical staff with a facility to visualise the data, and then take further steps if there are emergencies. It generates an alert that is pushed to a doctor's phone when abnormalities in health situations happen (Pathinarupothi et al., 2016).

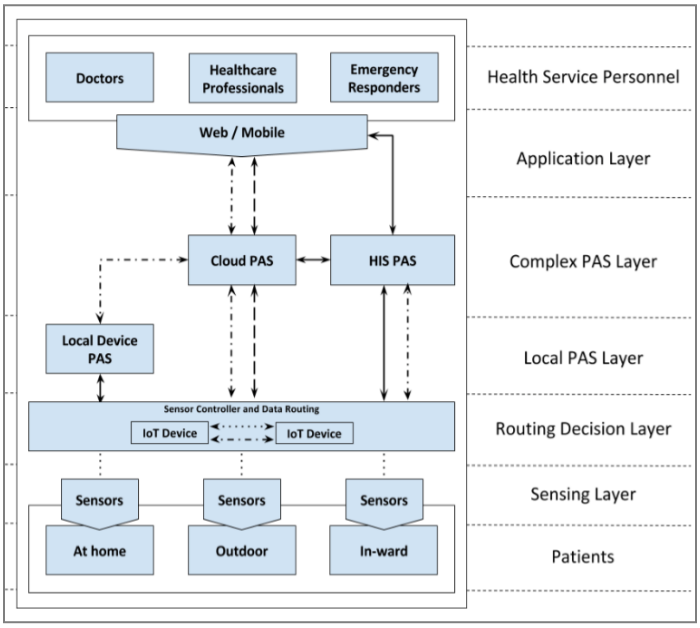


Figure 7.14: System Architecture for Remote Health Care Service
Source**:** (Pathinarupothi et al., 2016)

16. biSMART is a framework that was designed to identify ageing people's daily activities. It consists of three layers, which are UbiGATE, the server, and service provisioning. It is based on an AAL Cloud-based web app, to install hardware and software components easily. It allows easy and quick utilisation of software and hardware components. The framework can detect Daily Living Activities (J.Bellmunt et al., 2016). Figure 7.15 shows the framework.

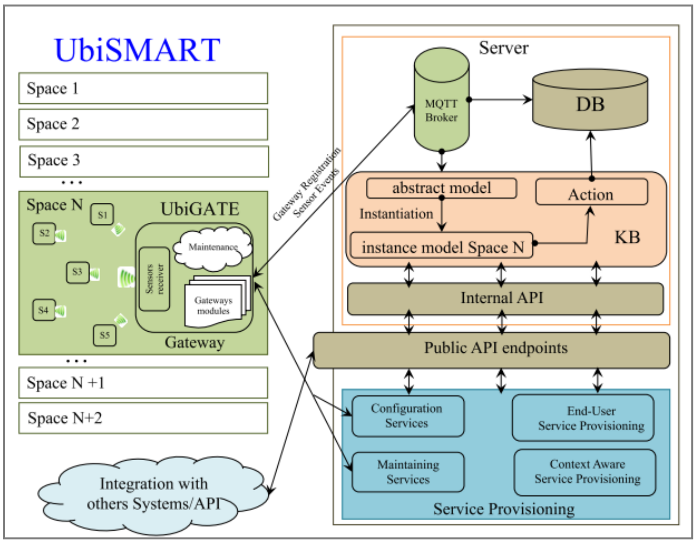


Figure 7.15: UbiSMART Framework
Source*:* (J.Bellmunt et al., 2016)

17. Architecture was developed to monitor a patient's health indicators, such as diabetes, heart and pressure. The system sends information, such as diabetes measurements, to a phone via Bluetooth. The patient answers some questions that are shown on his/her phone's screen. Then, a doctor can check this information to see whether it is in the range of normality or not. The system is able to send an alert to the doctor if the reading is out of range (Gómez et al., 2016).

There is no mention of the layers within the system. The system is a phone application that allows the patient to insert their workout routines, and the architecture of the system is shown in Figure 7.16.

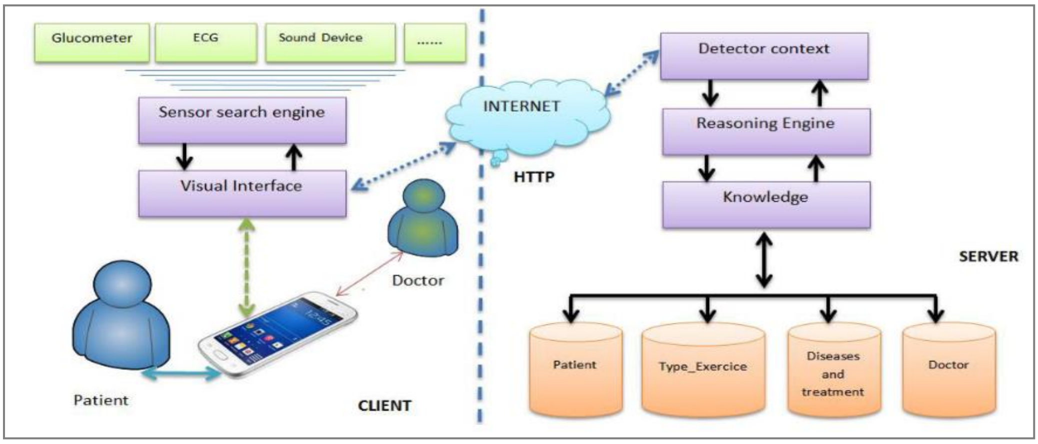


Figure 7.16: System Architecture
Source: (Gómez et al., 2016)

18. SilverLink is an architecture that was designed to monitor health-related motion and daily activities for senior citizens. It uses sensors for humans and objects located inside a user's home. In addition, the user is offered an SOS alarm wristband/pendant, which is activated by the user, in case of emergencies.

The emergency team contacts the user if they receive an alarm from him/her, and then assistance is provided to the user. The system has a web portal that allows families and caregivers to monitor the user remotely. The system also contains an analytical engine that detects any abnormalities, and then sends an alert (Chuang et al., 2016). The architecture of the system is shown in Figure 7.17.

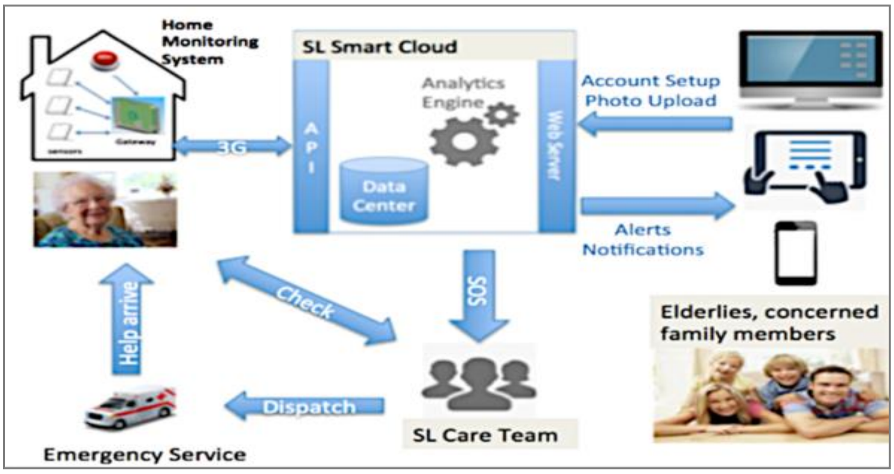


Figure 7.17: SilverLink Architecture
Source: (Chuang et al., 2016)

19. PlaIMoS is a technological platform that was developed to record and report electrocardiograms and heart conditions. It comprises wearable sensors, a network infrastructure, a fixed measurement station, a server, and apps, as illustrated in Figure 7.18. It allows doctors to set up the maximum and minimum for some parameters. The system can send a notification if the patient's data that was acquired from the sensors are exceeding the range of these parameters (Miramontes et al., 2017). Doctors can review and analyse the patient's data in real time. This system is used as a notification system, to send an alert to the Smart phone of the healthcare provider when an anomaly occurs.

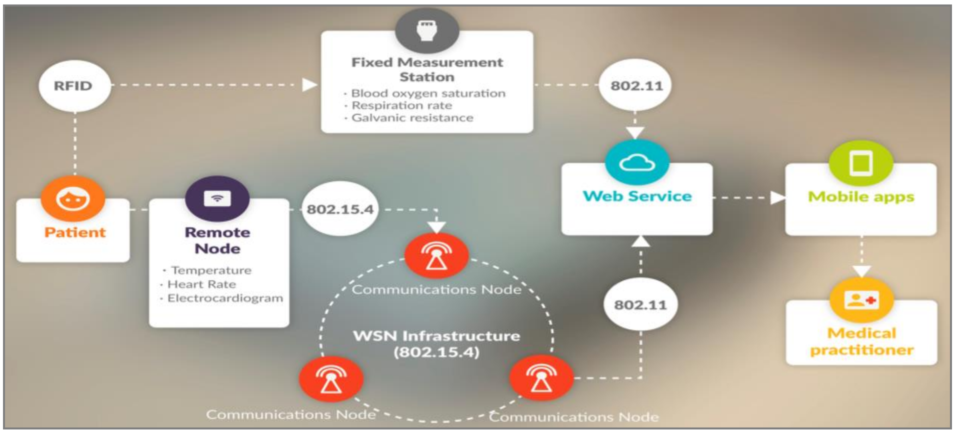


Figure 7.18: PlaIMoS Platform Architecture,
Source: (Miramontes et al., 2017)

20. A system was developed by Aihua (2017) to monitor if elderly people fall. It consists of a mobile phone and sensor unit. The user carries the sensor, which contains a microelectrometrical operating system. Bluetooth is used to transmit data from the sensor to the phone. The phone has an app that detects the fall of elderly people. When a fall is detected, an alarm is sent to an emergency contact. It is clear that the system is an application that does not cover all aspects of monitoring elderly people in their homes. Figure 7.19 illustrates the fall-detection system.

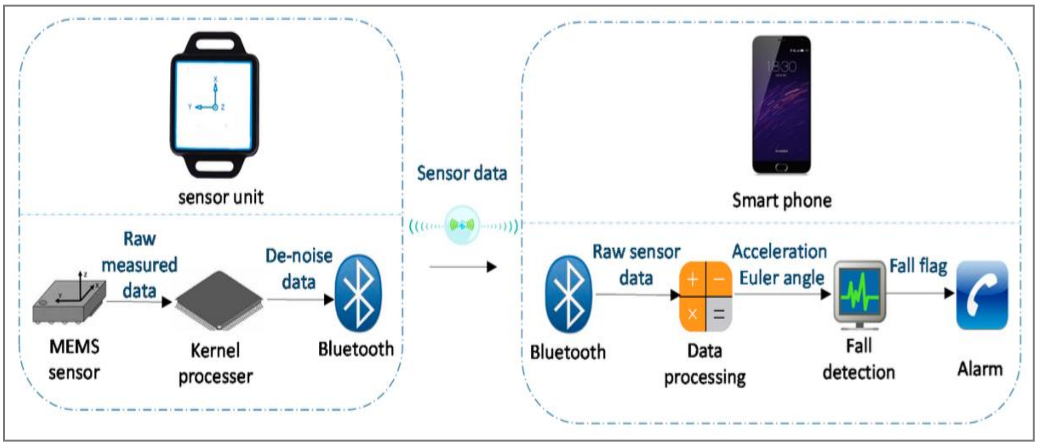


Figure 7.19: Fall Detection System
Source: (Aihua et al., 2017)

However, the literature review indicates that there is no professionally designed, platform, model or framework that can fulfill the needs or requirements of elderly people in the KSA. Therefore, the model we develop will be advocated to provide elderly people in the KSA with a better quality of life and to support them to live independently in their desired environments. It is developed based on a combination of layers that are mentioned in the literature review, and it covers and contains all layers and concepts that are investigated.

7.4: The Developed Conceptual Model - Ambient Assisted Living to provide a Home Proactive Monitoring System (AALHPMS)

The developed model will require that the homes of elderly persons are equipped with a set of sensors based on their needs, such as temperature sensors, emotion sensors, a camera, etc. The most important concerns for the model are cost efficiency, and that the sensors can be retrofitted in a cost-effective way. The sensors should be installed easily, be flexible to be updated, and not require remodeling of the home. Thus, the sensors will be positioned on walls, doors, floors, ceilings, and furniture. Furthermore, the elderly person can wear some of these appliances, such as the Smart watch, using wireless technology that makes retrofitting elderly persons' home feasible.

The contribution to knowledge involves addressing problems of the ageing population, which are rising in the KSA, by developing a Conceptual Model for using Ambient Assisted Living to Provide a Home Proactive Monitoring System for Elderly People in the KSA (AALHPMS).

The developed model can support stakeholders: decision makers, elderly people, and healthcare providers, in adopting the AAL technology as a standard foundation to provide elderly people with quality of life and the ability to live independently. The rationale behind developing the model incorporates the following characteristics:

- Uniqueness: the AAL technology is a new concept in the KSA, and to the best of our knowledge, there are no studies that have investigated its use in the KSA to address the ageing population's challenges and issues. Thus, this developed model is unique
- Efficiency: cost is a critical factor that affects the adoption of any technology. The model proposes a low-cost installation of tools, such as Smart watches, sensors, appliances, maintenance, etc. This is a competitive feature to adopt for implementing the model, making it efficient and designed to retrofit to existing homes
- Responsiveness and Proactivity: elderly persons are very vulnerable to health issues. In some cases, instead of reacting after something has occurred, it is important to step back and be proactive, by monitoring the health of the elderly. It is extremely important to prevent the need for medical intervention, as well as ensuring it if and when it becomes necessary. Therefore, the developed model is both responsive and proactive
- Flexibility: the sensors are installed easily and are flexible, so that they can be updated, and do not require remodeling of the home. Thus, the developed model is flexible, using emerging technology and wireless systems.

7.4.1: The First Iteration of the Development

In this section, we describe the model's architecture, which includes seven layers, and the operational iterations of the developed model.

7.4.1.1: Data Acquisition and Processing (DAP) Layer

The first layer can be defined as the process of transferring signals, such as from heartbeat, motion sensors, etc., into a format that can be read (Pires et al., 2016). Most of the devices are equipped with Smart sensors, which enable devices to be connected to each other (Xu et al., 2014). Therefore, DAP is responsible for collecting real-time data from different input sensors with different formats.

The data are captured from elderly people in accordance with the specification and instrumentation of each sensor, such as a Smart watch that measures heart rate. The data are transmitted via Bluetooth technology, or any wireless technologies that can support the connection. Then they are synchronised by using a mobile app, or by using a computer with installed connectivity. The data are then transferred wirelessly to a web portal.

7.4.1.2: Communication Structure (CS) Layer

The communication structure is the backbone of the developed conceptual model. The major role of the CS layer is to connect devices together and enable them to share data. For this iteration, the CS consists of four types of network: Bluetooth, wireless, ZigBee and Internet. It requires the availability of the Internet, which will help upload the data from the Smart devices, such as a phone or a laptop, to the online portal, via the wireless network, and will connect the Smart devices with the sensors via Bluetooth, as shown in Figure 7.20. This should not present problems, because in the KSA, at the end of the second quarter of 2017, Internet penetration reached 76%, Internet users increased to 24.1 million, and the total mobile broadband subscriptions were 25.25 million (Communications and Information Technology Commission, 2017).

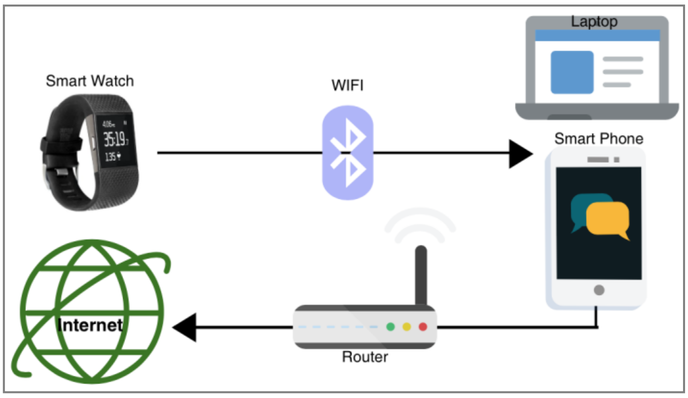


Figure 7.20: An Overview of the Communication Structure

7.4.1.3: Data Integration (DI) Layer

The data integration layer is the combination of data silos from different sources, which then delivers a coherent and consistent valuable view of the data (Srivastava et al., 2012). Therefore, the data for this developed model will be collected from different sensors installed in the home of the elderly person, including motion sensors, temperature sensors, Smart watch, etc. This layer is the core of the developed conceptual model, because it integrates and combines into the data hub different structures and formats of data retrieved from different sensors. The data collection should be more efficient and consistent, since it is filtered, cleaned, and uploaded to the hub.

The process of data integration consists of four types of databases: lifestyle, motion, and sensor databases, and also (subject to the elderly person approval) an imagery database, as shown in Figure 7.21.

This layer is responsible for storing and saving all applications and software into a hub. The hub can be a warehouse that integrates different data and converts them to valuable and meaningful information. The information can then be processed through the knowledge-reasoning layer using a rule-based expert system.

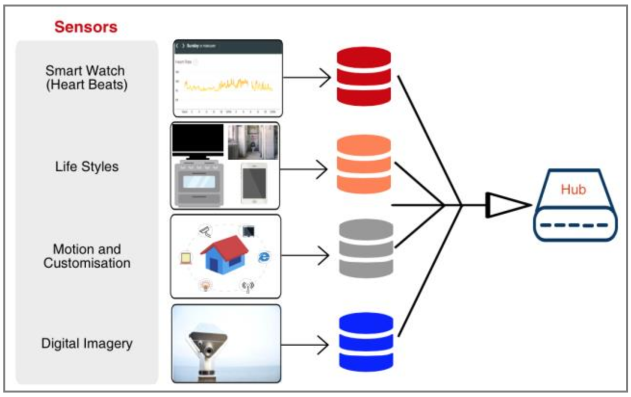


Figure 7.21: An Overview of the Data Integration

7.4.1.4: Cloud Computing (CC) Layer

Cloud computing is '*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g.,, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*' (Mell & Grance, 2011). Cloud computing can be described as a technique that provides computing resources through the Internet (Avram, 2014).

Cloud computing in the KSA is an emerging IT model, which changes the common traditional pattern.

The services that are provided by cloud computing are valuable and beneficial. The significant advantages of cloud computing are the cost saving and the increases in service efficiency (Alharthi et al., 2015; Alharbi et al., 2016). The annual IT budget of an organisation can be reduced by 10-20% when shifting to cloud computing (KPMG, 2014).

Cloud computing allows the conceptual model to store and share the applications, software, processing resources and data to Smart devices. The Cloud provides the conceptual model with efficiency, and the ability to react and respond to the system quickly, whenever and wherever it is required. This layer is the primary layer that connects the data integration layer with the reasoning layer.

7.4.1.5: Knowledge Reasoning (KR) Layer

The developed conceptual model is designed for using a knowledge based and reasoning system, to build a decision support system (DSS) for AALHPMS. A rule-based system will assist in making proactive decisions. It processes and analyses large amounts of data and translates them into information and knowledge. A knowledge-based system (KBS) can be used to transfer knowledge to resolve issues and problems (Tripathi, 2011). It can also produce intelligent actions, using rule-based reasoning. Rule-based reasoning is considered to be the foundation of KBS (Liao, 2003). Rule-based reasoning is responsible for collecting solutions based on the data (Bichindaritz et al., 1998; Syed-abdullah et al., 2015) acquired from different sensors. The information from AALHPMS can be used to provide proactive solutions that support medical actions. An example of a rule-based system is given in Section 8.3.

7.4.1.6: Visualisation (V) Layer

In real life, people favour graphics, maps, visuals and charts that present realistic views of the information (AlYami et al., 2016). The proposed system takes real-time information and from it delivers knowledge that is shown as patterns. The knowledge is generated by knowledge reasoning, which translates the integrated data into meaningful visualisations. It provides insights to the users.

The system's visualisation can be seen and monitored by a mobile, laptop, or any smart devices. It is considered a value-added service, especially for the elderly person's family, relatives and healthcare providers. This layer is used for visualising the data that are received from sensors and stored in the Cloud. Eventually, visualisation assists us in making representations that express a story about the data.

7.4.1.7: Proactive Control Centre (PCC) Layer

Elderly people are subject to physical and mental issues. Their health is completely different from when they were younger, and health is a very complex process. Therefore, health problems might happen suddenly and accidentally. Sometimes, taking action after things have happened is not effective. Thus, instead of reacting when something occurs, it is extremely important to step back, and be proactive by monitoring the health of elderly people, and thus preventing the need for medical actions.

A Proactive Control Centre (PCC), which helps to predict the type of issues, and problems that could happen to the elderly person.

Figure 7.22 illustrates the first iteration of a developed conceptual model using Ambient Assisted Living to provide a proactive monitoring system (AALPMS).

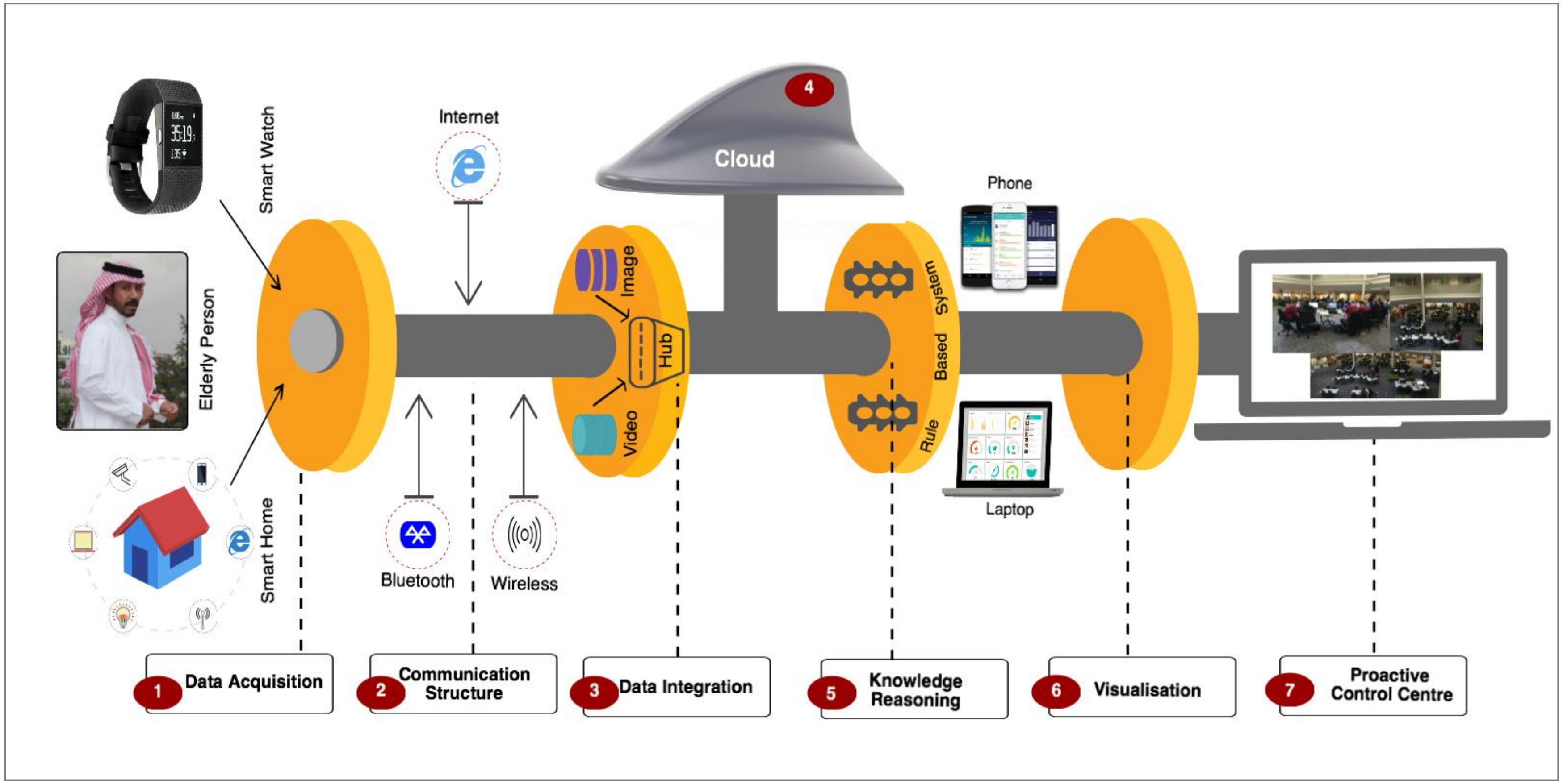


Figure 7.22: The First Iteration of Developed Conceptual Model using Ambient Assisted Living to Provide a Proactive Monitoring System (AALPMS) for Elderly people in the KSA at Home

7.4.2: The Second Iteration of Development

The first iteration of the conceptual model has been enhanced according to the outcomes of experimental cases that are mentioned in Chapter 6, where the visualisation layer was integrated with the proactive control centre layer, to give a six-layer overall model as shown in Figure 7.23.

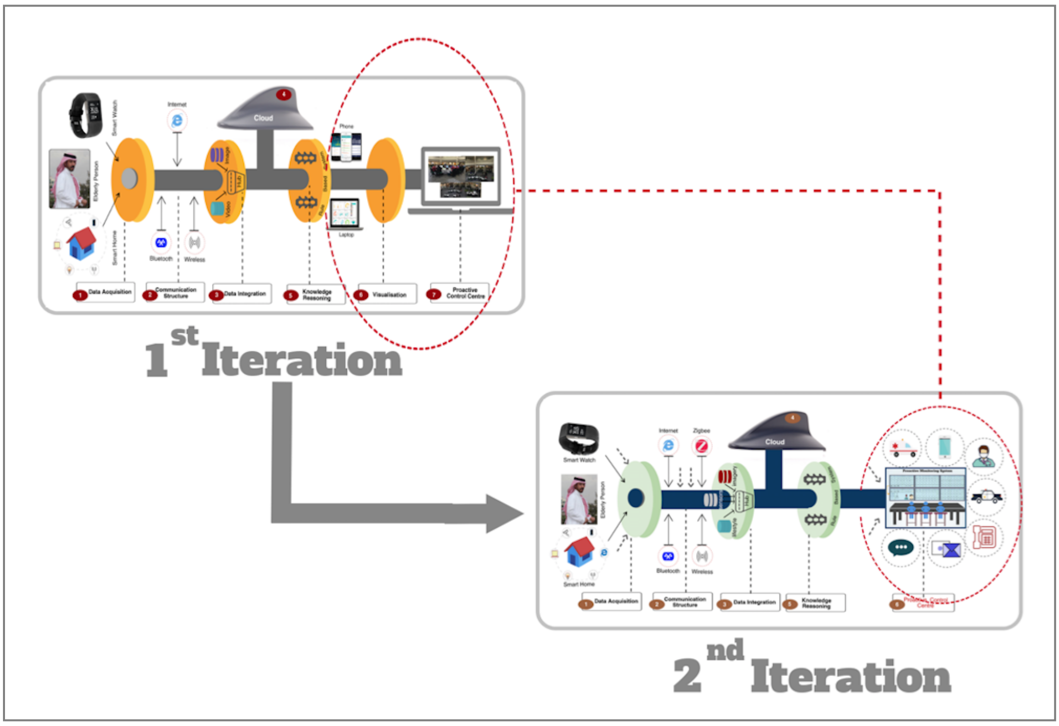


Figure 7.23: The Design Iterations of the Developed Model

The improvement in the second iteration of the conceptual model (AALHPMS) determines the actions/services that can be delivered to the elderly people. Therefore, the first five layers of the first iteration remain the same, and the sixth layer of the Second Iteration is an integration of the previous sixth and seventh layers (First Iteration) as outlined as follows:

Proactive Control Centre (PCC) Layer

A Proactive Control Centre (PCC) consists of a multiscreen, which has the functions of a proactive monitoring system (PMS). The prototype PMS will assist in predicting the type of issues and problems that could occur in monitoring elderly persons based on knowledge reasoning, thereby supporting appropriate actions that are tailored to the specific problems for the individual. The multiscreen displays a dashboard that contains the elderly person's details, the maximum and minimum heart rate, the elderly person's location and lifestyle and overall condition as shown in Figure 7.24**.**

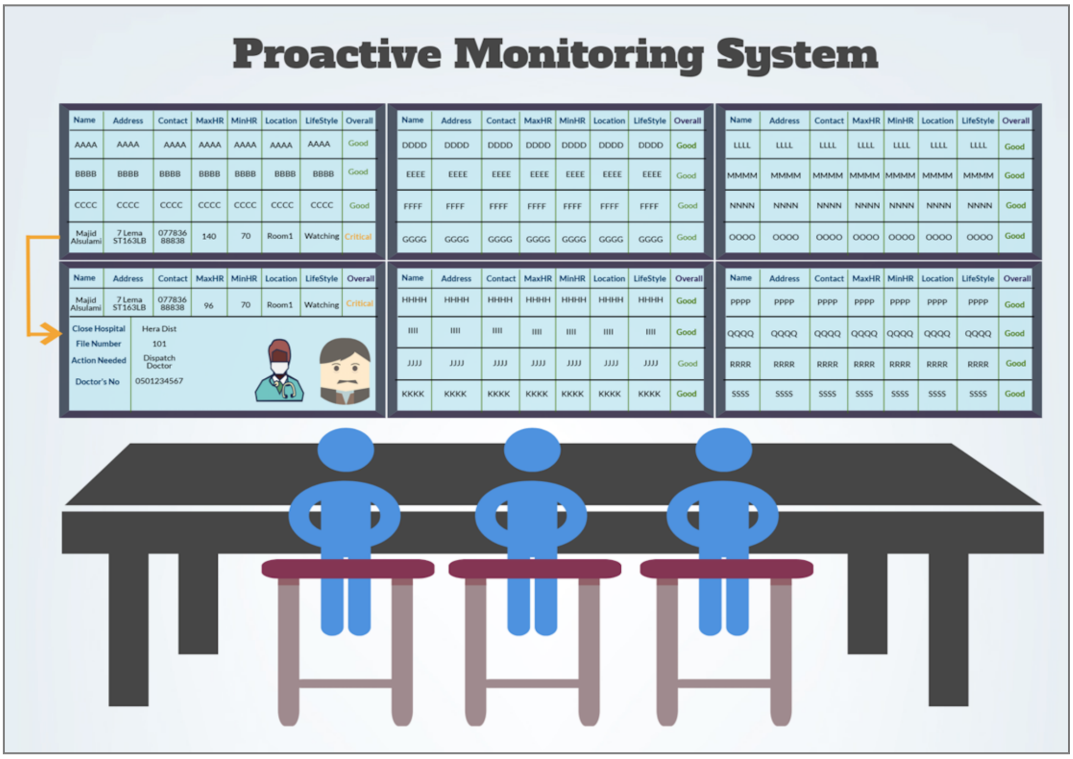


Figure 7.24: The Dashboard for Monitoring an Elderly Person

Monitoring an elderly person requires him/her first to register in PMS by following the operational processes described in Figure 7.25.

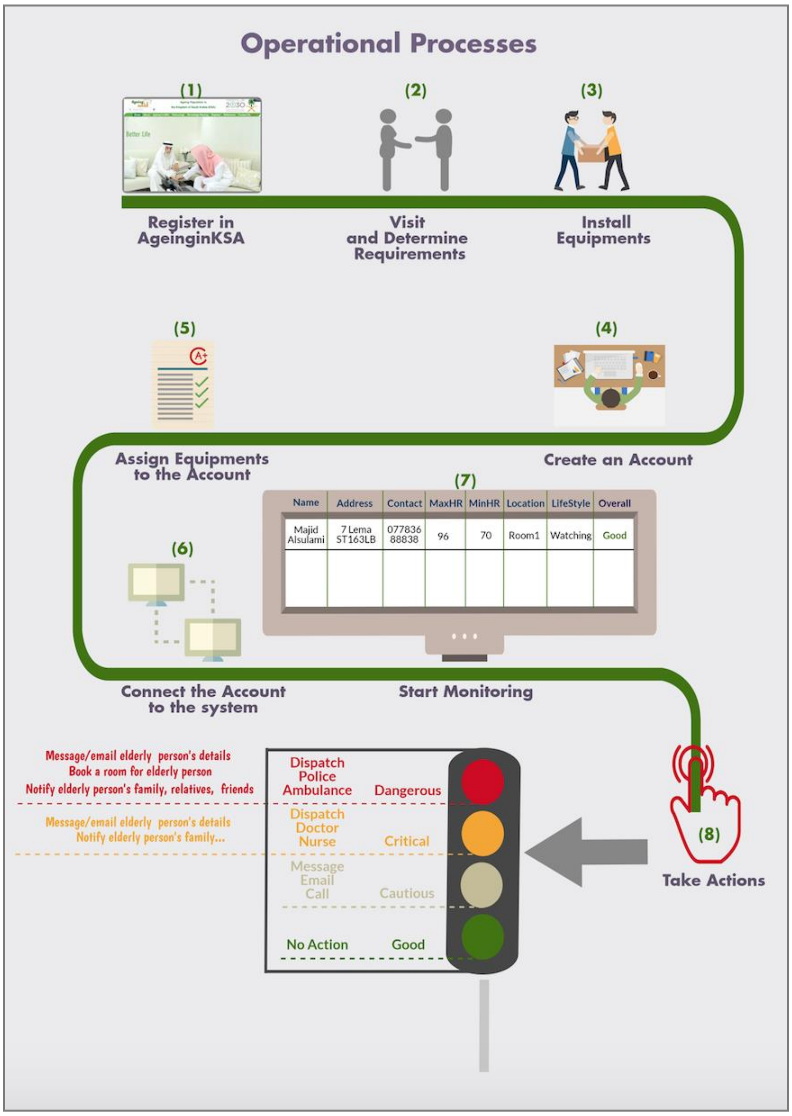


Figure 7.25: The Operational Processes for PMS

The services that can be delivered to elderly people include: calling; texting, alerting and emailing the elderly person, contacting families, contacting relatives or carers, visualising daily activities, early reports to families, relatives, carers etc, dispatching a doctor or a nurse and calling an ambulance or the police. In the enhanced model, more sensors and networks can be added, based on the needs of the elderly person. Therefore, it is an agile conceptual model, which is able to add or remove services based on the circumstances of elderly people as shown in Figure 7.26.

The enhanced conceptual model will assist the Saudi Government and elderly people to adopt an AAL technology that supports early intervention at home and minimises the long-term consequences of health issues.

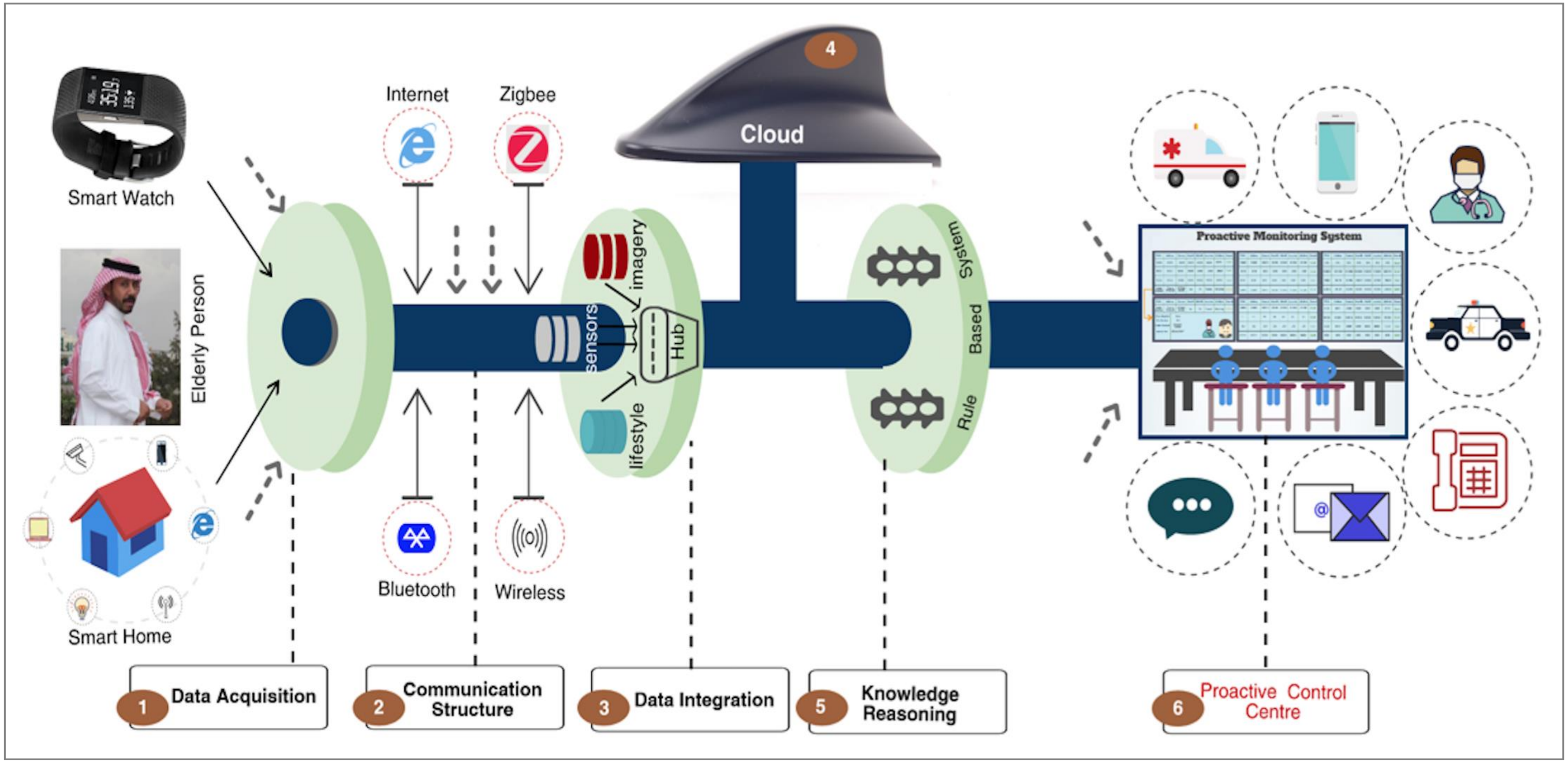


Figure 7.26: The Enhanced Conceptual Model using Ambient Assisted Living to Provide a Home Proactive Monitoring System (AALHPMS) for Elderly People in the KSA (Final Version)

7.5: Conclusion

Elderly people are often not willing to be treated in a traditional manner, as they have been in the last decades. They want and demand a technological solution that provides them with a good quality of life and supports them to live longer at their own homes.

This chapter documents the study and design for a system that would meet this demand by means of a new AAL Home Protective Monitoring System, AALHPMS, to be implemented in the KSA.

In the first part of this chapter, twenty existing AAL projects and applications (from 2012 to 2017) were reviewed and analysed in terms of operational layers and concepts and were used in a first principle design for the developed model of the proactive monitoring system.

The first iteration of this developed model is composed of seven layers: data acquisition and processing, communication structure, data integration, cloud computing, knowledge reasoning, visualisation and proactive control centre.

This first iteration of the conceptual model has been enhanced with a second iteration, according to the outcomes of experimental cases shown in Chapter 6. This improvement of the conceptual model (AALHPMS) determines the actions/services that can be delivered to the elderly people. These services are: calling; texting; alerting and emailing the elderly; contacting families; contacting relatives or carers; visualising daily activities; early reports to families, relatives, carers etc; dispatching a doctor or a nurse, and calling an ambulance or the police. This produces an agile conceptual model, for which services can be added or removed, based on the circumstances of the elderly people.

In this enhanced conceptual model (Second Iteration) the visualisation layer was integrated with a proactive control centre layer (First Iteration), to give a six-layer overall model.

We developed the system so that elderly people can be monitored remotely by their families, relatives/caregivers, and automatically by the AALHPMS. The data collected from a variety of sensors, will be processed and integrated, and will be delivered, via a knowledge-based system, to provide indicators that guide the

AALHPMS to implement appropriate actions in normal or emergency conditions.

Our system is based on cost efficiency and is designed so that it can be retrofitted to existing homes. This enhanced conceptual model would help to save significant amounts of money, which could be spent by the government to help overcome issues related to ageing. Our system can deliver a 24/7 monitoring system and proactive services, actions and feedback.

The ability of AALHPMS to react before issues happen, provides elderly people with a better quality of life, the possibility of living longer, support in doing some of their daily activities, and support for living independently and safely at their homes. Knowledge reasoning will be the key layer that guides the conceptual model, either to visualise the data to be seen by family, relatives, or caregivers, or to detect early emergency conditions and provide a variety of healthcare services.

Chapter 8: Knowledge Dissemination

8.1: Introduction

The previous chapter presented the research and development for the conceptual model. The development of the conceptual model consisted of two iterations, and the final model included six layers.

In this chapter, we define and discuss the knowledge management and the knowledge creation processes, which can assist in sharing the knowledge among individuals. The SECI model is considered to be the most documented knowledge model to convert and create knowledge between tacit and explicit. The SECI model can be used in the *virtual place* to create and share knowledge among individuals and groups. This knowledge can be managed using Web 2.0. Therefore, Web 2.0 is considered to be a technological tool that can be used to create and share knowledge via forums, blogs, Wiki, etc. Therefore, we designed a website to include these technological tools for the purpose of creating and sharing knowledge. An overview of the website, which is called Ageing in KSA (AgeinginKSA.org) is outlined in this chapter.

8.2: Knowledge Management (KM)

8.2.1: Definition of Knowledge

Knowledge is defined as '*justified true belief*'. It is considered as dynamic and can be created by social interactions among organisations and individuals. It is described as context-specific, since it is created in a specific space and time (Nonaka, 1994; Dalkir, 2005; King, 2009; Nonaka et al., 2000). Knowledge is '*information that is synthesized and contextualized to provide value. It is information with the most value. Knowledge consists of a mix of contextual information, values, experiences, and rules*' (Pearlson & Saunders, 2013).

Knowledge can assist organisations to create value (Dalkir, 2005), and it can be used to create new initiatives (Githii, 2014). It is considered to be a crucial resource, which can help organisations to retain a sustainable competitive advantage in a dynamic and competitive economy (Wang & Noe, 2010; Nonaka et al., 2000). In addition, knowledge can provide solutions to issues and problems by interpreting information (Githii, 2014).

8.2.2: Types of Knowledge

There are three types of knowledge. Significant research has indicated that tacit and explicit are types of knowledge (Karamitri et al., 2017; Dalkir, 2005; Nonaka, 1994; Kaiser et al., 2008; Nonaka et al., 2000). Tacit knowledge can be found in the human mind and body, such as skills, experience, ideas, and insight. Tacit knowledge is hard to be presented in the form of documents or with any other methods. Explicit knowledge can be articulated and communicated in format and technique approaches by systems and processes (Dahalin & Suebsom, 2008; Dalkir, 2005; King, 2009; Nonaka, 1994). Explicit knowledge includes people's held knowledge that can be followed, documented, saved, and recognised (Karamitri et al., 2017). However, there is a third type of knowledge, called implicit, which is '*knowledge that can be expressed in verbal, symbolic or written form, but not yet expressed*' (Lee, 2001). However, some studies do not differentiate between tacit and implicit knowledge (Pathak, 2014; King, 2009), while others differentiate between them and define tacit as: '*knowledge that cannot be written down*' and implicit as: '*that can be written down but has not been written down yet*' (Dubois & Wilkerson, 2008).

8.2.3: Knowledge Creation Processes

Knowledge creation can be identified as '*the process of creating and making individual's knowledge available*' (Nonaka, 1994). Considerable research has proposed processes to create knowledge. According to Soo et al. (2002) knowledge can be created by three processes:

- Generating knowledge from internal and external sources
- Internalising and integrating information, and know-how being extracted from contacts and sources
- Applying the knowledge by using applications.

Magd & Hamza (2012) described a sample list of knowledge management processes that was proposed by Galagan (1997), which includes:

- The generation of new knowledge
- The assessment of knowledge from external sources
- The representation of knowledge in software, database and documents
- The embedding of knowledge in services, products or processes
- The transformation of existing knowledge in an organisation

- Using available knowledge to make decisions
- The facilitation of knowledge growth over incentives and culture
- The measurement of the value of knowledge assets and knowledge management impact.

Zollo & Winter (1999) described how an organisation can create knowledge through accumulating new experiences, articulating or sharing knowledge with others, and then codifying this knowledge so that it can be made available and usable.

However, the most widely documented model for creating knowledge is the model that was developed by Nonaka & Takeuchi (1995), which reflects Japanese culture (Pathak, 2014; Galagan, 1997; Chatti et al., 2007; Ali et al., 2014; Natek, 2016; Panahi et al., 2012; Magill & Magill, 2010; Harncharnchai & Derrauiche, 2009). Essa (2011) carried out a literature review and indicated that some of the studies he investigated suggested that all SECI modes can be considered as traditionally Japanese. Other studies mentioned that not all SECI modes can be considered as embodying traditional Japanese values. Therefore, this should be considered and adapted when applying this model in Saudi Arabia (Almuayqil et al., 2015).

Nonaka et al. (2000) proposed a model of knowledge creation that is composed of three concepts: 1) the SECI model, which is a procedure of knowledge creation between tacit and explicit knowledge; 2) *ba*, which is a shared context; and 3) knowledge assets, which are the inputs, outputs, and moderator. These three concepts should be interacting with each other in order to formulate the knowledge spiral, which creates knowledge.

8.3: SECI Model

There are four knowledge creation processes, which are called SECI Modes as follows (see Figure 8.1):

8.3.1: Socialisation:

This is a process of transferring tacit to tacit knowledge, which refers to tacit knowledge being shared among people without formal discussions, as in observations, imitation, and practice (Nonaka et al., 2000).

8.3.2: Externalisation:

This is a process of transferring tacit to explicit knowledge, which refers to tacit knowledge being articulated into explicit knowledge, as in the building and sharing of paradigms and metaphors through formal discussions (Nonaka et al., 2000).

8.3.3: Combination:

This is a process of transferring explicit to explicit knowledge, which refers to the making of multiple explicit knowledge sources, as in structuring mission statements and other strategic documents through formal discussions (Nonaka et al., 2000).

8.3.4: Internalisation:

This is a process of transferring explicit to tacit knowledge, which refers to explicit knowledge being associated back to tacit knowledge, as in 'learning by doing' (Nonaka et al., 2000).

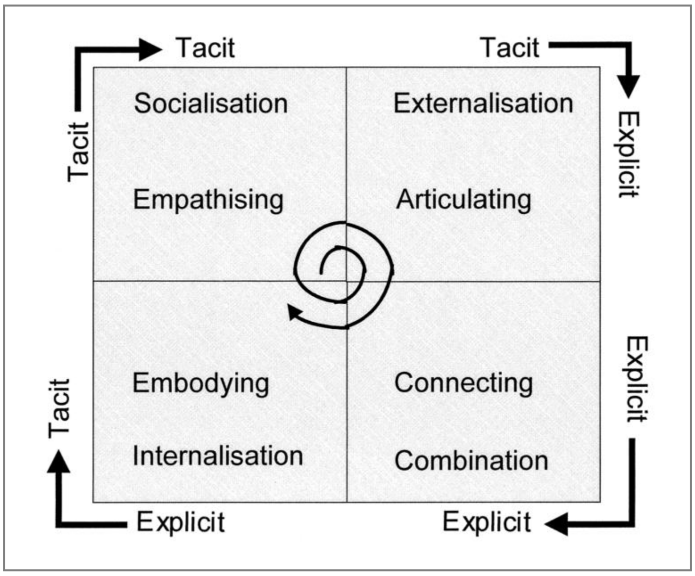


Figure 8.1: The SECI Model
Source: (Nonaka et al., 2000)

8.4: The concept of `*Ba*'

Knowledge requires a concept to be created. Therefore, this concept can be created by *ba*. *Ba* is a shared space that can be considered as a foundation and can encourage knowledge creation. The categories of this space are virtual, physical, mental, or a combination of them (Nonaka & Konno, 1998; Nonaka et al., 2000). However, *ba* can include space and time together.

Further, *ba* can be defined as '*a shared context in which knowledge is shared, created and utilised*'. In fact *ba* is the space where knowledge is created by interpreting information (Nonaka et al., 2000).

Nonaka & Konno (1998) & Nonaka et al. (2000) have indicated that there are four types of *ba*, which are related to the four modes of the SECI model.

8.4.1: Originating Ba

Originating *ba* can be described as a space where individuals interact face-to-face to share mental feelings, emotions, and experience models. It can provide a context for socialisation. It is a situation where emotions such as trust, care, love and commitment emerge, framing the foundation for knowledge conversion among people.

8.4.2: Interacting Ba

Interacting *ba* can be described as the interaction of collective and face-to-face actions, where individuals' capabilities and mental models are transformed and shared into mutual terms and ideas. It can provide a context for externalisation, where people's tacit knowledge is shared and expressed through dialogue among members.

8.4.3: Systemising Ba

Systemising *ba* can be described as the interactions of virtual and collective actions. It can provide a context for the combination of current explicit knowledge, which can be diffused to an enormous number of individuals in written format.

8.4.4: Exercising Ba

Exercising *ba* can be described as the interactions of virtual and collective actions. It can provide a context for internalisation. Virtual media, e.g., written manuals, is used to communicate explicitly.

8.5: Knowledge Assets

Knowledge assets can be the inputs, the outputs, and moderating factors of the knowledge creation processes. There are four categories for creating, acquiring, and exploiting knowledge assets, which are presented in Figure 8.2.

Experiential Knowledge Assets Tacit knowledge shared through common experiences • Skills and know-how of individuals • Care, love, trust, and security • Energy, passion, and tension	**Conceptual Knowledge Assets** Explicit knowledge articulated through images, symbols, and language • Product concepts • Design • Brand equity
Routine Knowledge Assets Tacit knowledge routinised and embedded in actions and practices • Know-how in daily operations • Organisational routines • Organisational culture	**Systemic Knowledge Assets** Systemised and packaged explicit knowledge • Documents, specifications, manuals • Database • Patents and licenses

Figure 8.2: The Four Categories for Knowledge Assets
Source: (Nonaka et al., 2000)

8.6: Definition of Knowledge Management

The overall purpose of KM is to '*make knowledge usable for more than one individual*' (Laal, 2011). Knowledge management can be defined as '*the process of applying a systematic approach to the capture, structure, management, and dissemination of knowledge throughout an organization in order to work faster, reuse best practices, and reduce costly rework from project to project*' (Dalkir, 2005). Girard & Girard (2015) reviewed more than 100 definitions and they concluded with two definitions, which are:

- Knowledge Management is 'the process of creating, sharing, using and managing the knowledge and information of an organization'.
- Knowledge Management is 'the management process of creating, sharing and using organizational information and knowledge'.

Ali et al. (2014) claimed that the main goal of KM is the ability to convert tacit knowledge to explicit knowledge. KM can assist organisations to benefit from knowledge resources (Kaiser et al., 2008). Furthermore, KM can deliver benefits to Communities of Practice (CoP), organisations and individual employees (Dalkir, 2005).

In the past few decades, managing knowledge has been considered to be a challenge. Therefore, the KM community has started developing applications and technologies in order to support practical applications and academic research. Additionally, in order to represent KM technologies and their applications, much research has investigated KM concepts, methodologies, functions, nature, tools, models, architectures and real-world implementations. Thus, it has become clear that the advancement of information and communication technology is an essential factor in KM. KM technologies can be categorised into seven areas: 1) information and communication technology (ICT); 2) KM framework; 3) data mining (DM);4) knowledge-based systems (KBS); 5) database technology (DT); 6) modeling and artificial intelligence (AI); and 7) expert systems (ES).

In particular, information and communication technology (ICT) plays an important role in decision support (Munoz Mata, 2011).

8.7: Rule-Based System for Proactive Monitoring Systems PMS

A rule-based system (RBS) is known as a ‘knowledge-based system’. RBS is considered to be a production system, which can work through rules, which encode expert knowledge. RBS is the most common option for creating a KBS. It can be represented through a set of ‘if…then’ condition rules, a set of facts, and an interpreter controlling the applications of the rules in order to determine the current status and assign appropriate solutions (Olajide et al., 2014).

The conceptual model was developed using a knowledge based and reasoning system, to build a decision support system (DSS) for AALHPMS. A rule-based expert system assists in making proactive decisions. It processes and analyses large amounts of data and converts them into information and knowledge. A knowledge-based system (KBS) can be used to transfer knowledge to resolve issues and problems (Tripathi, 2011). A KBS can produce intelligent actions and is used with rule-based reasoning. Rule-based reasoning is considered to be the foundation of KBS (Liao, 2003), and it is responsible for collecting solutions based on the data acquired from different sensors (Bichindaritz et al., 1998; Syed-abdullah et al., 2015). The knowledge will be viewed by AALHPMS and used to provide proactive solutions that support medical actions.

In this research, we used one activity, which is the heart rate of elderly person. A data set, based on experiments conducted in Chapter 6, was used as a database for designing a rule-based code using Python, as shown below. The data included heart rate, date, time and recipient's email, as shown in Figure 8.3.

```
# A code to send a message as an email when the condition is applied
import openpyxl
import smtplib
import os
from twilio.rest import TwilioRestClient
from email.mime.text import MIMEText
from email.mime.multipart import MIMEMultipart
print (os.getcwd())
wb = openpyxl.load_workbook('HeartRateData.xlsx')
sheet = wb.get_sheet_by_name('data')
# Number of the lines (rows) that were checked lines =100
for i in range(1, lines + 1, 1):
 HeartRate = int(sheet.cell(row=i, column=1).value)
 date = str(sheet.cell(row=i, column=2).value)
 time = str(sheet.cell(row=i, column=3).value)
 finalstr = "" + str(HeartRate) + "," + date + "," + time
 if (HeartRate >= 100 or HeartRate <= 70) :
 fromemail = "heartratecheck@gmail.com" # We used the same email
 toemail = "heartratecheck@gmail.com" # for the sender and receiver
 msg = MIMEMultipart()
 msg['From'] = fromemail
 msg['To'] = toemail
 msg['Subject'] = "Abnormal Activities"
 body = "Heart Rate: " + str(HeartRate) + ", Date : " + date + ", Time : " + time
 msg.attach(MIMEText(body, 'plain'))
 server = smtplib.SMTP('smtp.gmail.com', 587)
 server.ehlo()
 server.starttls()
 server.ehlo()
 server.login("heartratecheck@gmail.com", "***********")
```

```
text = msg.as_string()
server.sendmail(fromemail, toemail, text)
server.close()
```

Abnormal Activities - Heart Rate: 120, Date : 28/08/2017, Time : 1.55 PM	**7:39 am**
Abnormal Activities - Heart Rate: 70, Date : 28/08/2017, Time : 1.50 PM	**7:39 am**
Abnormal Activities - Heart Rate: 65, Date : 28/08/2017, Time : 1.45 PM	**7:39 am**
Abnormal Activities - Heart Rate: 67, Date : 28/08/2017, Time : 1.30 PM	**7:39 am**
Abnormal Activities - Heart Rate: 60, Date : 28/08/2017, Time : 1.25 PM	**7:39 am**
Abnormal Activities - Heart Rate: 110, Date : 28/08/2017, Time : 1 PM	**7:39 am**

Figure 8.3: The Received Email about Abnormal Activities after Running the Software Programme

As mentioned in Chapter 6, the heart rate can be over 100 bpm and less than 70 bpm, based on the activities that the elderly person does. However, when it is over or below the thresholds, this does not necessarily mean that there are abnormalities. Therefore, the code can contain a function for contacting the elderly person to check if he/she is performing some activity. If the person responds, this means that no abnormality occurred. In cases when there is no response from the person, then the email can be sent to a specified email address.

8.8: SECI Web Tools

Knowledge gaining and dissemination are considered to be one of the pillars of KM. Dissemination can also have relevant terminologies like transferring, exchanging, sharing, or diffusing knowledge (Karamitri et al., 2017). Many studies indicated that several instruments, tools or technologies can be used for knowledge creation, using an online communication via Web 2.0 (Hvorecky, 2012; Chatti et al., 2007; Panahi et al., 2013). The term Web 2.0 refers to the online applications, services, and websites that allow users to create, communicate, cooperate, and share information. There many applications and websites that can be represented as Web 2.0, some of which are wikis, blogs, social networking, Facebook, YouTube, etc. (Thomson, 2008).

The Internet has been speedily spreading and has changed people’s lives, becoming an essential part of their daily lives. The Internet can have a major impact on individuals and communities, and it influences their behaviour (Simsim, 2011). Therefore, this section presents a clarification of the usage of Web 2.0 for the four modes of SECI model: socialisation, externalisation, combination and internalisation:

8.8.1: Socialisation:

- Social networks are considered to be a tool for individuals and organisations that cross the limitations of time and location. They can encourage people to share and communicate tacit knowledge (Panahi et al., 2012; Natek, 2016; Chatti et al., 2007)
- Forums are a tool that enable knowledge creation between individuals and their learning from each other (Pathak, 2014; Natek, 2016). People can share knowledge by posting their knowledge via forums (Shakarami et al., 2016). The number of participants that can post their knowledge can be large, with extremely varied levels of participation (Lindgren, 2014)
- Community of Practice (CoP) allows a group of people to share knowledge and best practice through a face-to-face or virtual community. Wiki is a technology tool that can be used for CoP. It is a web that enables people to add and amend online knowledge (Murillo, 2008; Sztangret, 2014; Natek, 2016).

8.8.2: Externalisation:

- Wikis are used as a tool to articulate and convert tacit knowledge into explicit knowledge (Harncharnchai & Derrauiche, 2009; Sousa et al., 2010). A wiki is a collaborative website, which users can add to or amend through their contributions that can be available to everyone (Thomson, 2008; Menolli et al., 2015). The major advantage of a wiki is that it provides individuals with the capability to work on the same resources collaboratively (WikiEducator, 2005)
- Blogs allow users to post and store their contributions. Feedback comments can be posted in real time (Harncharnchai & Derrauiche, 2009). Blogs can deliver resources such as information on a specific subject, event or issue (Thomson, 2008). Blogs can support the externalisation process by providing opinions to everybody, and by offering a space to capture individual knowledge (Chatti et al., 2007)
- Forums can be used to externalise tacit knowledge into explicit knowledge, by asking questions and getting their answers interactively, between experts who have the tacit knowledge and users. The tacit knowledge is externalised by saving the questions and answers in forums (Magill & Magill, 2010).

8.8.3: Combination:

- Document is a form that provides the combination mode, by exchanging and expressing explicit knowledge. Users can use the same document to share, amend, add and update (Ali et al., 2014; Juntunen & Raisanew, 2015; Haag & Duan, 2012)
- Wikis create disseminated community knowledge that is updated. The captured knowledge can be converted into a social context (Chatti et al., 2007). It has the capability to provide a rapid method for using an online text as a contribution (Harncharnchai & Derrauiche, 2009). The main objective of a wiki is, for example, the web portal Nucleonica, which is a knowledge management perspective for delivering required technical documentation, or articles relevant to some applications (Magill & Magill, 2010).

8.8.4: Internalisation:

- Wikis can be used to disseminate and reuse knowledge sharing. Internalisation can be in place if users capture knowledge. The users are able to gain new knowledge when dealing with content, adding new content at the same time. Thus, collective knowledge will result (Sousa et al., 2010; Menolli et al., 2015). Wikis can enable the internalisation process to involve more professional cooperative writing (Menolli et al., 2015)
- Community of Practice (CoP) allows participants to share their skills and improve their understanding of their field by using wiki documents. CoP, via wikis and documents, encourage participants to share their concerns and ideas (Sarirete, 2011)
- Forums can internalise the knowledge by embedding beliefs and values into the users (Ali et al., 2014).

Therefore, to create and disseminate the knowledge that is with individuals, we designed a website that can be used as a technological web tool for sharing and creating interactive knowledge between individuals.

8.9: Purpose of the AgeinginKSA Website

The major concern for designing a website is to determine the purpose of building it (Crowder, 2010). Therefore, the purpose of building the website was to share knowledge with anyone interested in ageing in the KSA, to make the community aware of ageing in the KSA, to investigate the needs of elderly people, to assist elderly people to choose technology suitable for them, and to provide them with online training materials. This website is called Ageing in the Kingdom of Saudi Arabia (AgeinginKSA).

8.9.1: History of the Internet

The Internet is basically an international network of computing resources (Cengage, 2010). In 1977, the Internet was started when a message was sent from San Francisco to ARPANET (Oxford Brookes University, 2002). One of the many services provided by the Internet to users is the World Wide Web (WWW), which is a hypertext interface to connect to the Internet by using Hypertext Transfer Protocol (HTTP) via a Uniform Resource Locator (URL). A URL is used to identify each document's location on the web (Cengage, 2010).

In 1989, the World Wide Web (W3) was developed, and in 1994, the World Wide Web Consortium (W3C) was founded to guide the World Wide Web in its purpose (Arch, 2008). The aims of W3 are to allow access to all types of information easily, by using single easy interface, and to allow online information to be added easily, so as to raise its quality and quantity (Berners-Lee et al., 1992).

A web site can be defined as a '*collection of pages of information*' (Schifreen, 2009). A webpage can be viewed by using a browser and is linked to the World Wide Web. The main page of a website is called a home page, while the sub-page can be any page on the website except the home page (Google, 2017).

8.9.2: Website Development

Diffily (2006) defined website development as a procedure for building a new website or applying changes to a live website, for instance adding an important new part to an existing website. This was named as website ageing in the KSA. The procedure for creating a website involves eight stages, which can be described as follows:

- Planning: choose why you need a site and what to build
- Content: make a list of the substance you need
- Design: make an outline to show the substance
- Construction: compose the code and upload the material
- Test: ensure everything works appropriately
- Hosting: pick a domain name and discover a hosting provider to locate a website

on the Internet

- Publicity: build up activity by drawing attention to the site
- Review: audit the site at intervals, to ensure it succeeds.

8.9.2.1: Website Planning

Website planning is considered to be one of the important steps in the design of a website. It is a procedure to classify the users' needs and businesses' objectives, which can help start the Development Cycle (Diffily, 2006). The objectives of building this website were determined, based on the needs of stakeholders: healthcare providers, elderly social care, IT specialists and elderly people. Therefore, the stakeholders were asked about the objectives that should be achieved by building this website, through CoPs that were conducted.

Thus, the objectives of this website are:

- To make the community aware about ageing in the KSA
- To investigate the number of elderly people in the KSA
- To find solutions to assist elderly people in their daily activities and provide them with a better quality of life
- To investigate the needs of elderly people.

8.9.2.2: Website Content

Website content includes most information and applications that need to be available online for AgeinginKSA. It was very important to ensure that most information provided meets the needs of the stakeholders (Diffily, 2006). Therefore, we first investigated the relevant ageing websites to get an idea of their content. We investigated these ageing related websites: http://www.asaging.org, http://www.ageuk.org.uk, http://aginginamerica.org, http://www.healthyageing.eu and https://myageingparent.com.

8.9.2.3: Website Design

In order to design a successful website, Jakob Nielsen defined '*ten good deeds*' in web design that increase the usability of virtually all websites. The ten elements can be identified as follows (Jakob, 1999):

- Allocate the name and logo of the organisation on every page and hyperlink the logo to the home page
- Add a search engine
- Describe the headlines and page titles as simply as possible

- Build the page so as to simplify scanning
- Use hypertext to structure the content space
- Display product photos
- 'Use relevance-enhanced image reduction'
- Use link titles
- Ensure that all essential pages are accessible for users with disabilities
- Adopt what the best websites do in an appropriate technique.

A study conducted by Al-salebi (2010) indicated that there must be three significant features to make a good website. These features initiate four attributes of the website, which can be defined as personalisation, responsiveness, interactivity, and contrast.

The three features are:

Firstly, visual design is an important feature in the design of a good website. This feature depends on five issues, which are page layout, navigation, consistency, embedding pictures or flashes, and using appropriate colours. Secondly, readability is considered as an essential feature for making a readable website. This feature depends on three issues, which are font size, font family and font colour. Thirdly, content can be identified as the added value of the website. This feature depends on six issues, which are original content, credible content, grammar and structure of content, breaking the text's content into paragraphs, clean content and search engine.

In order to design a good website, designers should take into consideration some of the usability problems that may lead to failure. Therefore, it is important to evaluate the severity of web usability problems systematically (Nielsen & Loranger, 2006). This can assist the designers to overcome these issues at the beginning of the project of website designing. Nielsen & Loranger (2006) outlined in their book the most important factors that cause the failure of websites, which are:

- Search tools
- Findability (Information architecture, Category names, Navigation, Links)
- Page design (Readability, Layout, Graphics, Amateur, Scrolling)
- Information (Content, Product info, Corporate info, Prices)
- Task support (Workflow, Privacy, Forms, Comparison, Inflexibility)
- Fancy design (Multimedia, Back button, PDF/Printing, New window, Sound)
- Others (Bugs, Presence on web, Ads, New site, Metaphors).

The development and design of AgeinginKSA was built on the aforementioned literature review.

8.9.2.4: Website Construction

Website Construction is a procedure for translating design and content into code (Diffily, 2006). We used wix.com, which is a '*leading cloud-based development platform with millions of users worldwide*'. It has many templates that allow anyone to build a professional website easily (Wix.com, 2017). Therefore, we did not need to write any code to construct the design and contents. Diffily (2006) indicated that browser compatibility and screen resolution are very important for the website to be compatible with best practice (see Figure 8.7). Thus, AgeinginKSA was tested on Internet Explorer, Firefox, Safari and Google Chrome. The AgeinginKSA used 1024 pixels wide and 768 pixels high for the screen resolution, and was designed to be compatible with mobiles.

8.9.2.5: Website Test

Website testing is considered to be the process used to evaluate the website, based on the guideline agreements. It ensures that the website meets the minimum standards to achieve its goal and objective (Diffily, 2006). We have run many tests for AgeinginKSA.org using different website testers such as:

- Www.website.grader.com showing that the overall average for testing AgeinginKSA.org is 84 out of 100, as shown in Figure 8.4.

Figure 8.4: The Test Result by www.website.grader.com

- By using www.nibbler.silktide.com, the accessibility criterion indicated that it scored 9 out of 10, while the technology scored 8.5 out of 10 as illustrated in Figure 8.5.

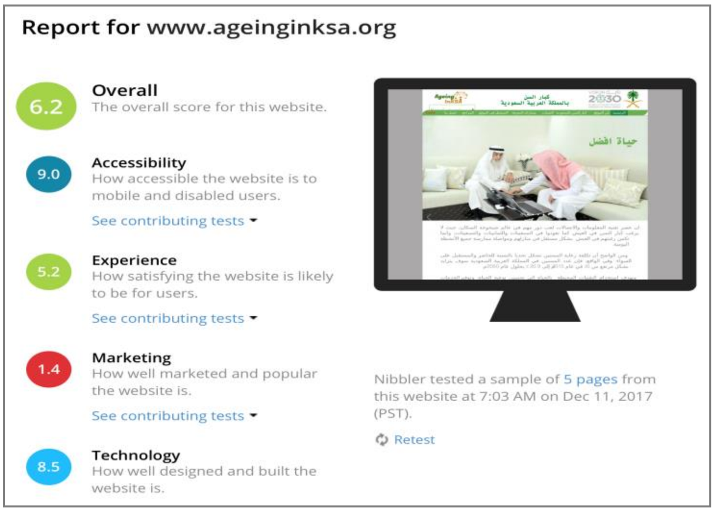


Figure 8.5: The Test Result by www.nibbler.silktide.com

➢ Www.pingdom.com presented a good performance with a grade of 80 out of 100 as shown in Figure 8.6.

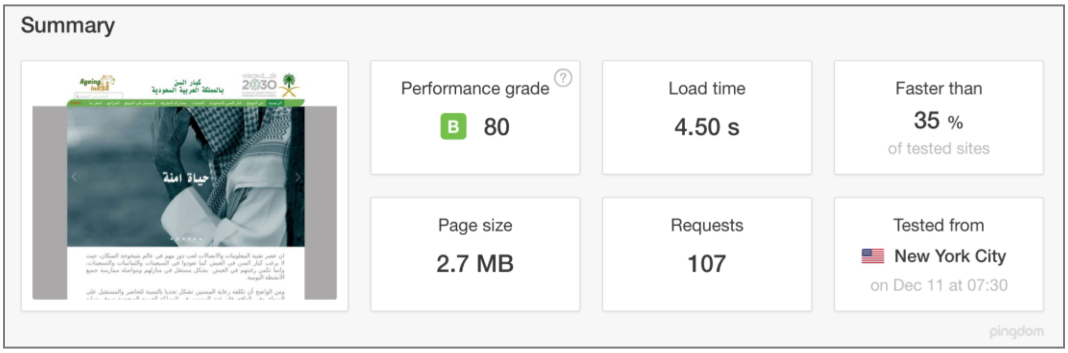


Figure 8.6: The Test Result by www.pingdom.com

➢ Www.powermapper.com proved that AgeinginKSA.org is compatible with most of the well-known browsers, and also with mobiles' browsers. It reported that there are no issues, as shown in Figure 8.7.

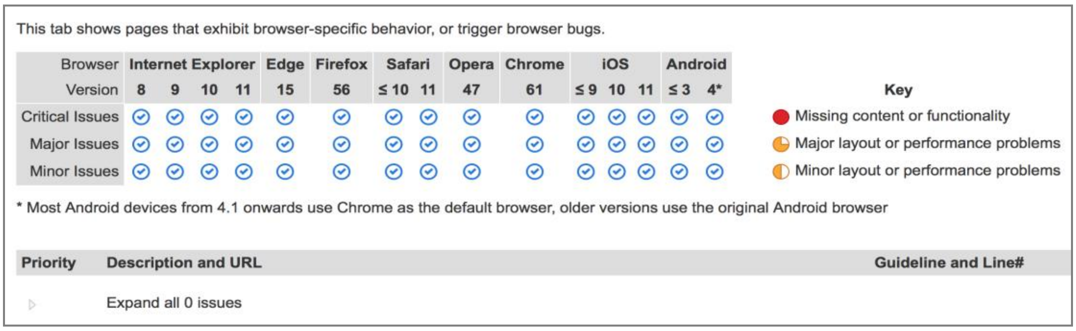


Figure 8.7: The Test Result by www.powermapper.com

- Www.search.google.com/test/mobile-friendly indicated that AgeinginKSA.org is designed to be mobile-friendly, as shown in Figure 8.8.

Figure 8.8: The Test Result by www.search.google.com

- Www.checkmycolours.com tested the colours that are used in AgeinginKSA.org, and reported no issues related to them as shown in Figure 8.9.

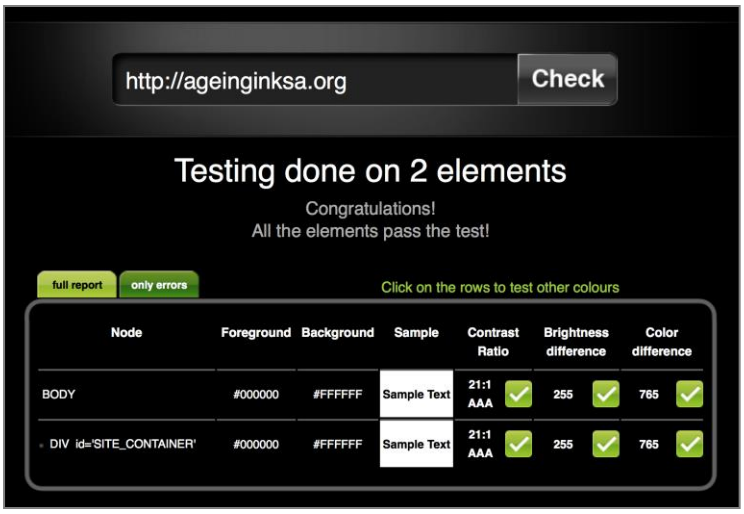


Figure 8.9: The Test Result by Www.checkmycolours.com

8.9.2.6: Website Hosting

Website hosting is a space in which the website is stored and can be accessed via the Internet (Diffily, 2006). Wix.com is the hosting provider that was chosen for the website, and the domain name is ageingingksa.org. We selected .org because AgeinginKSA is a non-profit organisation.

8.9.2.7: Website Publicity

The website was disseminated via a series of social communications, such as Twitter, Facebook, Linkedin, and using Instant Messages such as WhatsApp. In addition, Wix.com provides Search Engine Optimisation (SEO).

8.9.2.8: Website Review

According to the website's plan, reviewing the website indicates that the goal and objectives have been accomplished.

8.10: An Overview of the AgeinginKSA Website

At the first stage, AgeinginKSA was designed in the English language, and then, according to the results of the focus group that was held for the evaluation session (Chapter 9) and following requests to translate AgeinginKSA into the Arabic language, the Arabic website was designed covering the English and Arabic languages.

In this section, we explain the contents of AgeinginKSA.

8.10.1: Home Page of AgeinginKSA

A home page is considered the main page of a website that is navigated by users. It assists users to move between other pages in AgeinginKSA. It consists of a logo in the left corner, search engine, title of the website, and the vision 2030 of Saudi Arabia. It has many pages, which are about ageing in the KSA, technology, social media, registration, references and contacts. Figure 8.10 shows the English home page and Figure 8.11 illustrates the Arabic home page. It contains a slideshow with six images that reflect the meaning of ageing.

Figure 8.10: English Home Page of AgeinginKSA

Figure 8.11: Arabic Home Page of Ageing in KSA

The second part of the main page, which includes the contact number and email and the twitter account, is shown in Figure 8.12.

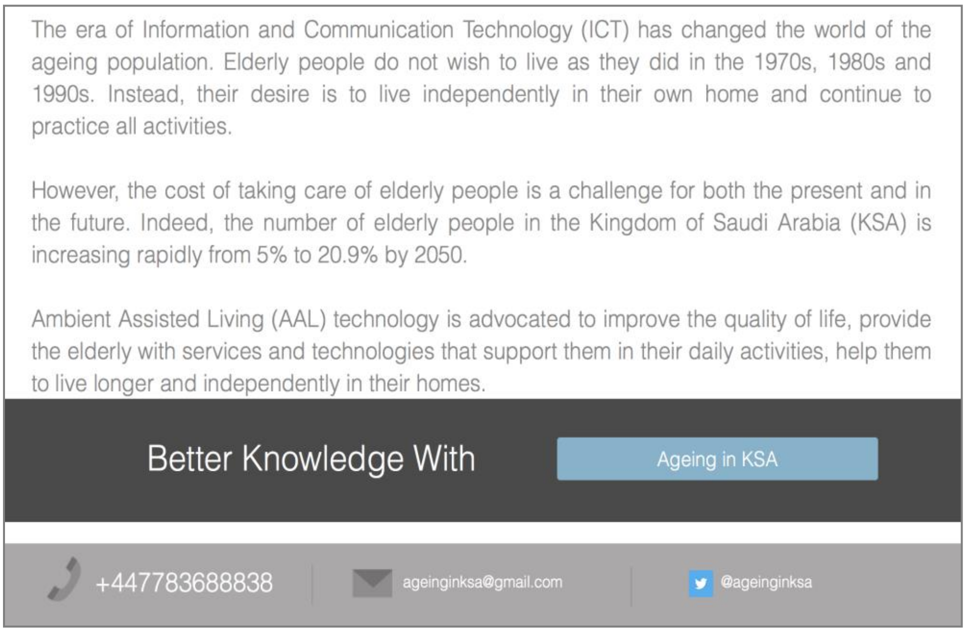


Figure 8.12: The Second Part of Main Page

8.10.2: About Page

The about page is composed of three sub-pages: objectives, context and team, as shown in Figure 8.13. The objectives sub-page is to clarify the purposes of the AgeinginKSA website, which are to collaborate with ministries, researchers, healthcare providers, elderly people, families and related organisations and people, in order:

- To make the community aware about ageing in the KSA
- To investigate the number of elderly people in the KSA
- To find solutions to assist elderly people in their daily activities and provide them with a better quality of life
- To investigate the needs of elderly people.

The context sub-page presents the idea of designing AgeinginKSA, while the team sub-page introduces a short resume of the researcher and his supervisors.

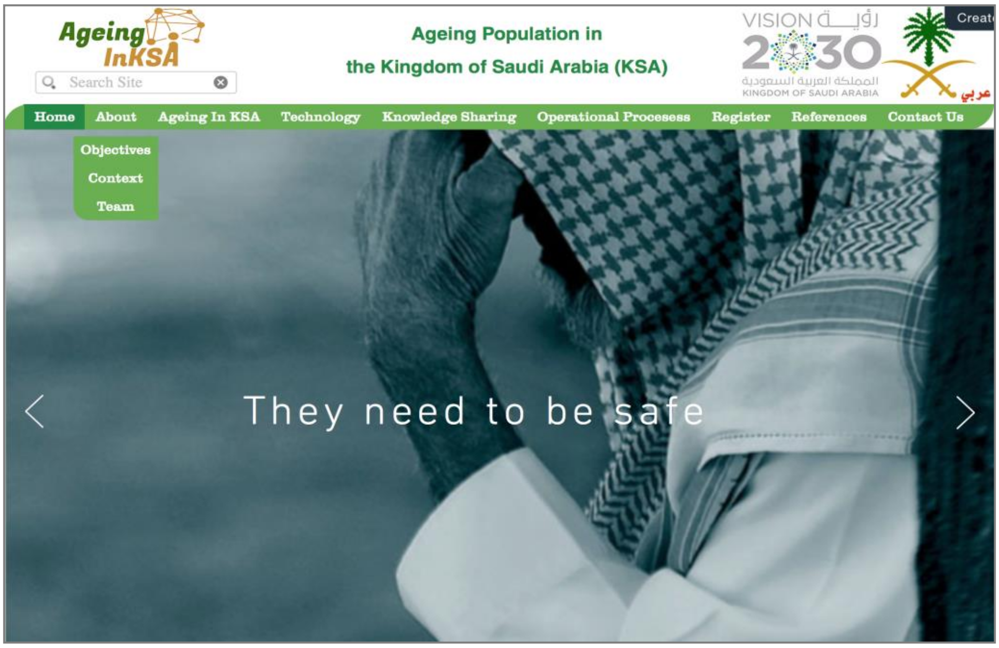


Figure 8.13: About Page of AgeinginKSA

8.10.3: Ageing in KSA Page

The ageing in KSA page is composed of two sub-pages, which include ageing figures and causes of the ageing population, as illustrated in Figure 8.14. The ageing figures sub-page presents some statistics about the ageing population in the KSA, and the second sub-page indicates the causes of ageing, which are fertility, mortality and international immigration, as discussed in Chapter 2.

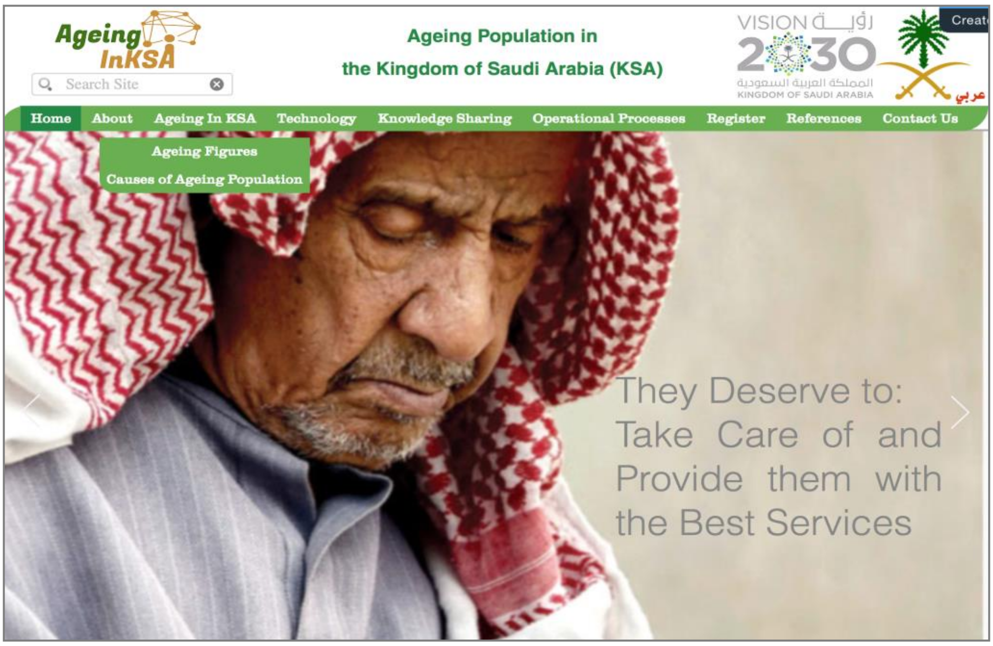


Figure 8.14: Ageing in KSA Page

8.10.4: Technology Page

This page contains five sub-pages and explains AAL technologies, which are Smart homes, Assistive robotics, Mobile and Wearable sensors and e-Textiles.

Figure 8.15: Technology Page

8.10.5: Knowledge Sharing Page

As mentioned in Section 8.3, many technological tools can be used to share knowledge. This page describes the tools that we used in the website, as illustrated in Figure 8.16.

Figure 8.16: Knowledge Sharing Page

8.10.6: Operational Processes Page

This page explains the processes to subscribe in the monitoring system that we proposed. Figure 8.17 presents the processes that are suggested.

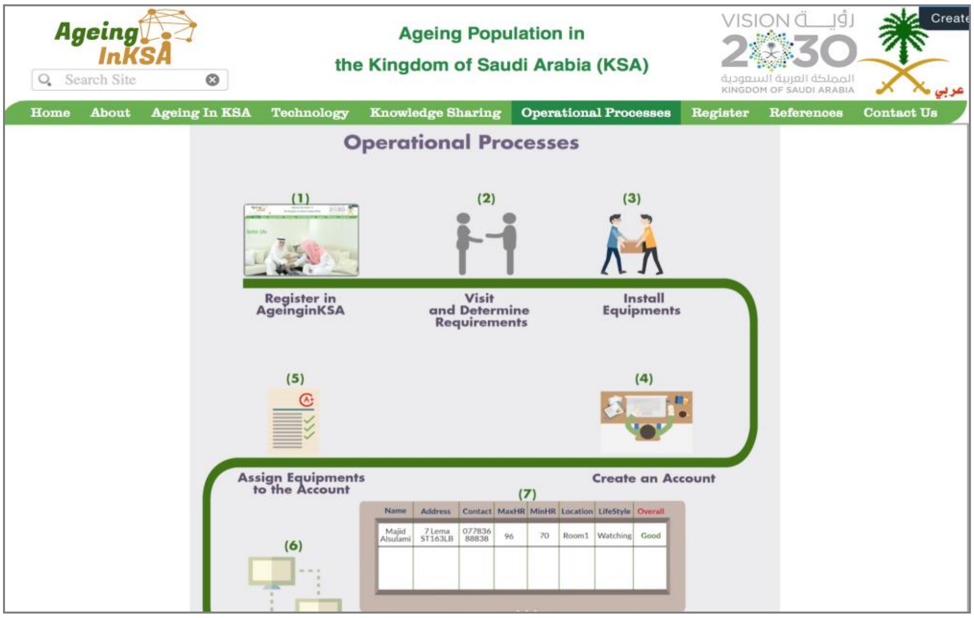


Figure 8.17: The Operational Processes for Subscribing in the Proposed Monitoring System

8.10.7: Registration Page

This page consists of a form that allows people to register with the website, in order to subscribe to the monitoring system, as shown in Figure 8.18.

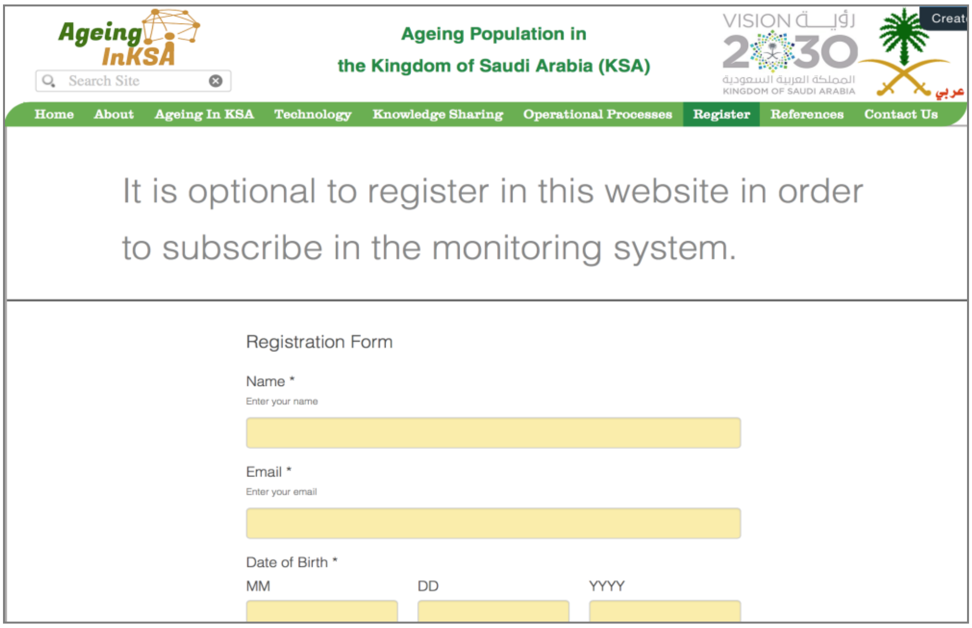


Figure 8.18: Registration Form

8.10.8: References Page

This page contains all references for the images that have been used, and the references for the contents of the website, as shown in Figure 8.19.

Figure 8.19: References Page

8.10.9: Contact Us Page

In order to ask for further help or more information about the website, a help page was designed and is outlined in Figure 8.20.

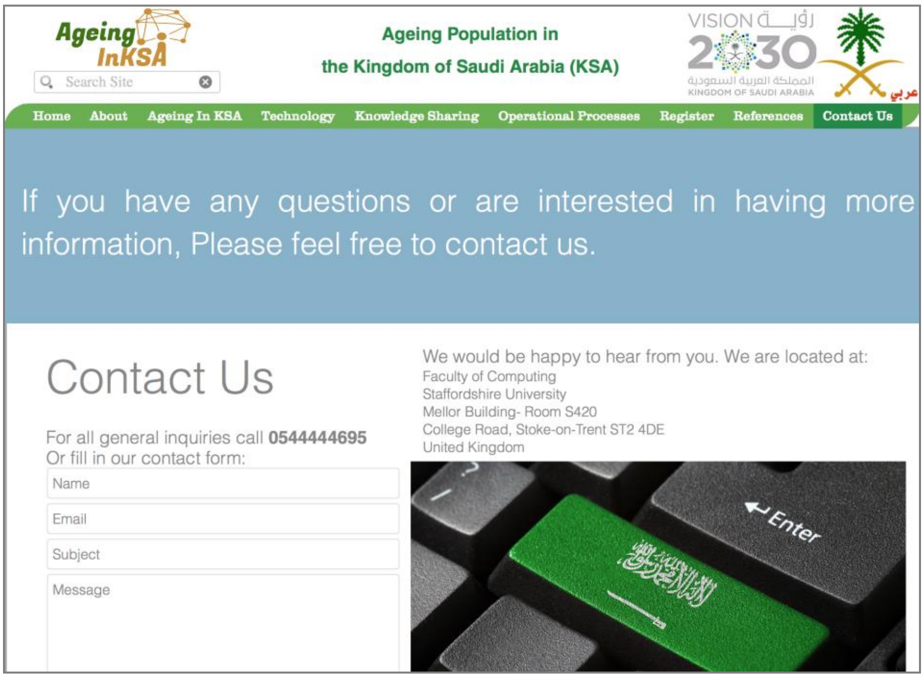


Figure 8.20: Contact us Page

8.11: Conclusion

An important aspect of knowledge is its sharing and dissemination among individuals. Knowledge management is a tool that can be used to create and manage knowledge. Knowledge dissemination concepts were used to develop a rule-based system for the PMS, as well as for the web, which can be used to share knowledge using different web tools.

Different types of knowledge were considered, such as tacit and explicit, as well as implicit. These types of knowledge can be shared by using the SECI model, which consists of four modes: socialisation, externalisation, combination and internalisation.

Socialisation can be shared by using social media, forums and CoPs. Externalisation can be shared by using tools such as wikis, CoPs and forums. Combination can be shared by using documents and wikis, while internalisation can be shared by using wikis, CoPs and forums.

Therefore, to share and disseminate knowledge, a website (AgeinginKSA.org) was designed and implemented based on eight phase standards. A detailed description of this AgeinginKSA website is provided, and this website was tested by using different website testers, and, overall, it passed all the tests.

The implementation of a specially designed website, AgeinginKSA, makes the whole system developed by this research easily and widely accessible, particularly for aged people, and it will be proposed for adoption throughout the KSA.

Chapter 9 discusses the development of evaluation instruments to the conceptual model, evaluate SECI web tools, and the usability of the AgeinginKSA website. Then the analysis of the evaluation results is presented and discussed.

Chapter 9: Evaluation

9.1: Introduction

In the previous chapter, we defined the knowledge management and the knowledge creation processes. The SECI model and web tools for using the SECI modes to share knowledge were explained. The knowledge dissemination concepts were used to develop a rule-based system for the PMS and the web, which can be used to share knowledge, using different web tools.

This chapter includes the development of instruments to evaluate the main contributions of this research, which are the conceptual model, the SECI web tools, and AgeinginKSA website. The web tools such as wikis, blogs, forums and CoPs, which cover the four SECI modes, are outlined. A focus group with nine participants was assembled in the King Abdul Aziz University. The participants of the focus group consisted of three stakeholder groups: elderly people, healthcare providers, and IT specialists. The results and discussions of the evaluations of the conceptual model, of the SECI web tools, and of the AgeinginKSA website are presented and analysed in this chapter.

9.2: Validation

Validation can be defined as the '*process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model*' (Oberkampf & Trucano, 2002). Oberkampf & Trucano (2008) indicated that '*Validation is not a procedure for testing scientific theory or for certifying the "truth" of current scientific understanding .... Validation means that a model is acceptable for its intended use because it meets specified performance requirements*.' Experiments can be used to validate a model (Oberkampf & Trucano, 2008). Therefore, the validation of the conceptual model that was developed in Chapter 7 was undertaken by the experiments that were conducted and analysed in Chapter 6.

9.3: Evaluation

One of the objectives of this research is to evaluate the conceptual model, the SECI web tools that are used to disseminate knowledge, and the usability of the AgeinginKSA website that was designed and implemented.

Evaluation can be defined as '*the process of determining the extent to which objectives have been attained*'(Steele, 1970). Usability can be defined as '*a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process*' (Nielsen, 2012). The usability evaluation process can be defined as '*an effective method by which a software development team can establish the positive and negative aspects of its prototype releases, and make the required changes before the system is delivered to the target users*' (Issa & Isaias, 2015).

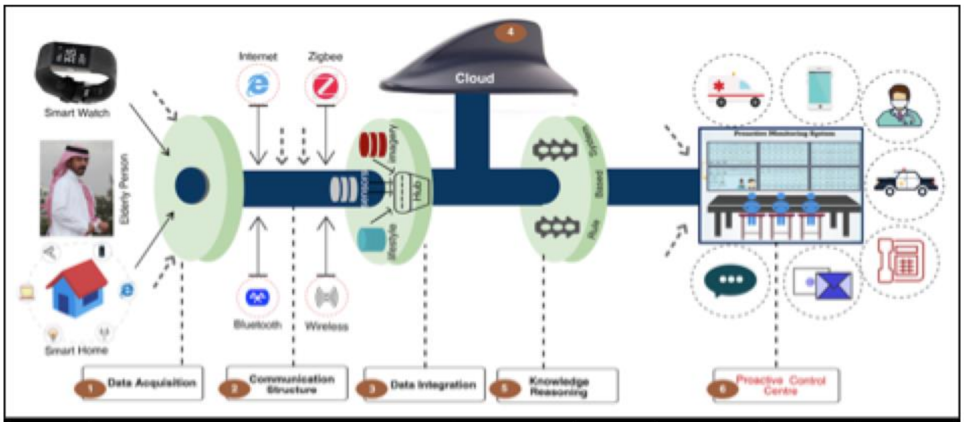
9.4: The Development of the Evaluation Instruments

Three concepts were considered in the evaluation development:

- ➢ The ability of the conceptual model to fulfil the requirements of stakeholders
- ➢ The effectiveness of the SECI model to disseminate knowledge using web tools
- ➢ The usability of the AgeinginKSA website.

In order to evaluate the conceptual model, we developed an instrument that consisted of closed-questions, using a Likert scale measurement as outlined in Table 9.1.

Table 9.1: An Instrument to Evaluate the Conceptual Model



#	Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Agree
1	The conceptual model provides induction and help.					
2	The conceptual model is consistent and standard.					
3	The conceptual model looks aesthetic and of minimalist design.					
4	The services provided by the conceptual model are sufficient.					
5	The six layers of the conceptual model are fully represented.					
6	The conceptual model matches the real world needs.					
7	The conceptual model is intuitive to understand.					

The Likert scale is composed of a 5-point scale (Strongly Agree: 5 to Strongly Disagree: 1). The instrument consists of seven statements that reflect the layers of the conceptual model, based on the CoP discussions.

Furthermore, in order to evaluate the SECI web tools, we developed an instrument, which used a Likert scale measurement; the Likert scale consisted of a 5-point scale (from Strongly Agree: 5 to Strongly Disagree: 1), as illustrated in Table 9.2.

Table 9.2: An Instrument to Evaluate SECI Web Tools

SECI Modes	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Socialisation	Social media is efficient to socialise knowledge relevant to AgeinginKSA.					
	Forums are efficient to socialise knowledge relevant to AgeinginKSA.					
	Community of Practice is efficient to socialise knowledge relevant to AgeinginKSA.					
Externalisation	Wikis are efficient to externalise knowledge relevant to AgeinginKSA.					
	Blogs are efficient to externalise knowledge relevant to AgeinginKSA.					
	Forums are efficient to externalise knowledge relevant to AgeinginKSA.					
Combination	Document is efficient to combine knowledge relevant to AgeinginKSA.					
	Wikis are efficient to combine knowledge relevant to AgeinginKSA.					
Internalisation	Wikis are efficient to internalise knowledge relevant to AgeinginKSA.					
	Community of Practice is efficient to internalise knowledge relevant to AgeinginKSA.					
	Forums are efficient to internalise knowledge relevant to AgeinginKSA.					

In order to evaluate the usability of the AgeinginKSA website, we used heuristic evaluation. This is considered an effective and efficient method to evaluate a website and identify usability problems (Hasan, 2014; Layla et al., 2013). Therefore, we used the guidelines for heuristic evaluation that were proposed by Nielsen (1995a), and severity ratings for usability problems that was outlined by Nielsen (1995b), as shown in Table 9.3, with a rating scale from 0 to 4 for the following:

0 = I don't agree that this is a usability problem at all

1 = Cosmetic problem only: it does not need to be fixed, unless extra time is available on the project

2 = Minor usability problem: fixing this should be given low priority

3 = Major usability problem: important to fix it, so should be given high priority

4 = Usability catastrophic: imperative to fix this before the product can be released.

Table 9.3: An Instrument to Evaluate AgeinginKSA Website

Heuristics	Statements	Rating Scale				
		0	1	2	3	4
Visibility of system status	The AgeinginKSA can provide users with feedback while working on the website, within an appropriate time. (e.g., header explains screen contents, action when object is chosen, cursor points the selected item.					
Match between system and the real world	AgeinginKSA uses terms familiar to users and information appears logical and natural. (e.g., Icons are familiar, menu in logical order)					
User control and freedom	AgeinginKSA provides users with freedom and control. (e.g., users can cancel any action, users can stop interacting at any time).					
Consistency and standards	AgeinginKSA is built to be consistent and standardised. (e.g., each window has a title, Icons are labelled, menu names match the meaning).					
Error prevention	AgeinginKSA can address error handling. (e.g., the number of character spaces is presented in the text box, warning message shown when error occurs).					
Recognition rather than recall	AgeinginKSA offers instructions on how to use it. (e.g., name of pages).					
Flexibility and efficiency of use	AgeinginKSA is designed to be used by experienced and inexperienced users.					
Aesthetic and minimalist design	AgeinginKSA demonstrates relevant contents, which are relevant to the stakeholder's needs.					
Help users recognize, diagnose, and recover from errors	AgeinginKSA provides error messages that can be used to advise and provide instructions for correction and recovery. (e.g., form of support).					
Help and documentation	AgeinginKSA provides help and documentation. It can be easily searched, and information is easily found. (e.g., form of support).					

9.5: A Focus Group in the KSA

One of the significant advantages of carrying out a focus group is the richness and depth of information that can be gained and learned. The acceptable size for a focus group can be between 6 and 10 participants (Bartels et al., 2003).

Therefore, a focus group was assembled on August 2017 in the King Abdul Aziz University, Jeddah, Saudi Arabia, in order to evaluate the conceptual model, to evaluate the SECI web tools that can be used for knowledge sharing, and to evaluate the AgeinginKSA website.

Nine participants (three IT specialists, three healthcare providers and three elderly people) (see Figure 9.1) attended, and the Arabic language was preferred. However, the presentation of the concept was written in the English language but was presented in Arabic and the sessions were recorded. The focus group was divided into two sessions as follows:

- The 1st session was an introduction to the conceptual model, KM, SECI Model and AgeinginKSA website. This session took 40 minutes
- The 2nd session was about evaluating the conceptual model, the SECI web tools for knowledge dissemination, and the AgeinginKSA website. This session took 60 minutes.

Figure 9.1: The Focus Group, Place at King Abdul Aziz University

9.6: Scenario of the Evaluation

The evaluation started in the second session. The researcher clarified the aims of the evaluation and the techniques to be used. The participants were provided with information and guidance to encompass ethical matters, such as the ability to withdraw from the survey at any time. The information relating to the instruments was online, and the relevant links were sent to the participants. The participants were able to use their phones to participate in the online information session.

9.7: Demographic of the Participants

It was important to engage participants relevant to the concepts of the evaluation. Three groups of stakeholders were involved in this evaluation process. The three concepts (conceptual model, SECI web tools, and AgeinginKSA website) are related to elderly people; therefore, those were involved. The healthcare providers were considered as the second stakeholders, because they have responsibilities to support elderly people and provide for their needs. Finally, the IT specialists have the ability to implement the conceptual model and design websites.

All participants were selected carefully in order to make sure they had sufficient knowledge about evaluating the concepts of the developed system.

The age group 20–40 years old made up 55.56% (5 participants) of respondents, the age group 41–59 made up 11.11% (1 participant), and 33.33% of respondents (3 participants) were above 60 years old, as shown in Figure 9.2.

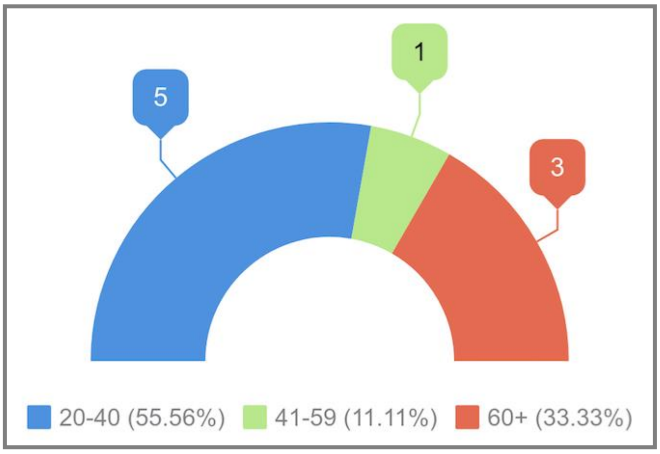


Figure 9.2: Demographics of Participants

9.8: Results and Discussions

9.8.1: Conceptual Model

The researcher and his supervisors defined seven statements in order to evaluate the conceptual model. The mean of the results was calculated for each group of participants, and then an overall evaluation for each group is presented. The analysis and discussions for the seven statements are as follow:

- **The conceptual model provides induction and help**

Two elderly people agreed with this statement, and one person chose neutral (mean = 3.67). Two of the healthcare providers strongly agreed, and one agreed with the statement (mean = 4.67). Two of the IT specialists agreed, and one strongly agreed with the statement (mean = 4.33). The overall evaluation mean for this statement was 4.22. Figure 9.3 shows the results for this statement.

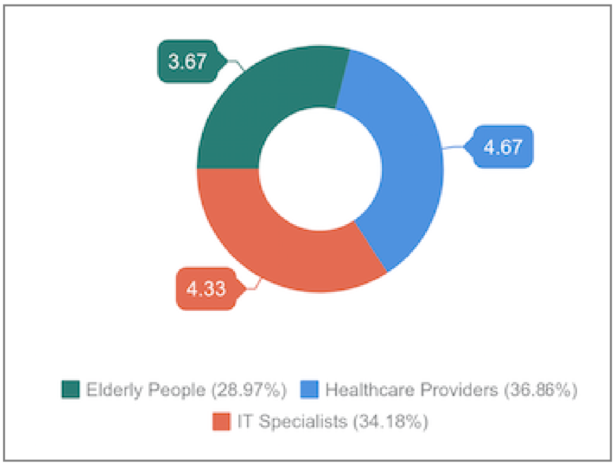


Figure 9.3: The Evaluation of the Induction and Help

➢ The conceptual model is consistent and standard

All the elderly people agreed that the conceptual model is consistent and standard (mean = 4). Two of the healthcare providers agreed, and one strongly agreed with the statement (mean = 4.33). Two of the IT specialists agreed, and one strongly agreed with the statement (mean = 4.33). The overall evaluation mean for this statement was 4.22, and Figure 9.4 shows the findings.

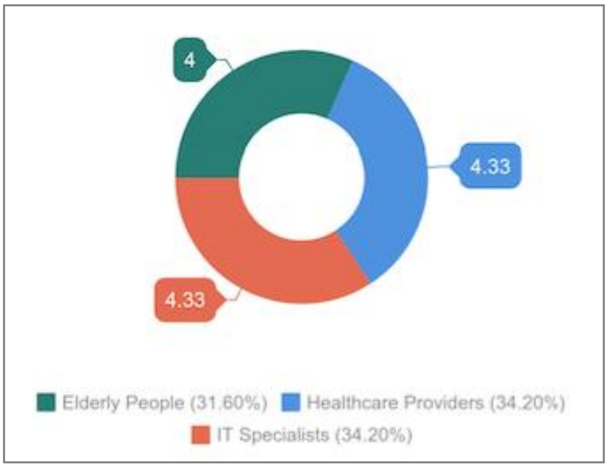


Figure 9.4: The Evaluation of the Consistency and Standards

➢ The conceptual model looks aesthetic and of minimalist design

Figure 9.5 illustrates the results of the third statement. Two of the elderly participants agreed, and one strongly agreed that the design of the conceptual model is aesthetic and minimalist (mean= 4.33). Two of the healthcare providers and of the IT specialists strongly agreed and one agreed, which leads to a mean = 4.67 for each group. The overall mean for evaluation of this statement was 4.56.

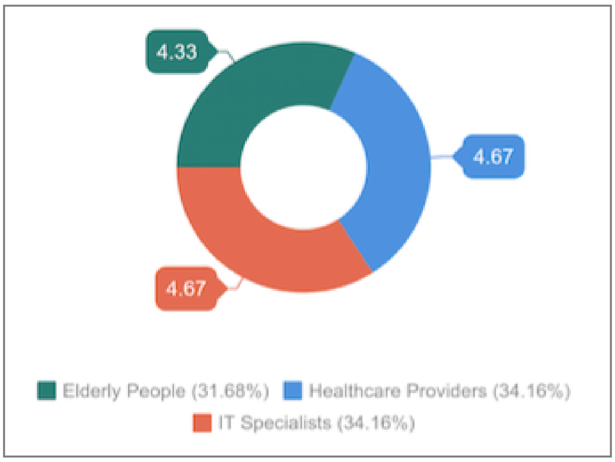


Figure 9.5: The Evaluation of the Design

➢ **The services provided by the conceptual model are sufficient**

The participants were asked about the services that are provided by the conceptual model in order to assess how sufficient they are. All the services were presented to the participants. All the elderly people agreed that the services are sufficient (mean = 4). Two of the healthcare providers agreed, and one strongly agreed with the sufficiency of services (mean = 4.33). Two of the IT specialists strongly agreed, and one agreed with the statement, which results in mean = 4.67. The overall evaluation mean was 4.33 and Figure 9.6 illustrates the mean for each group.

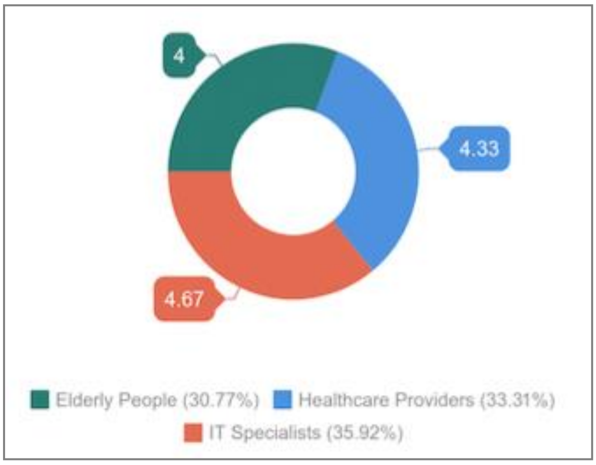


Figure 9.6: The Evaluation of the Sufficient Services

➢ **The six layers of the conceptual model are fully represented**

The six layers and their roles were explained to the participants. All the elderly people agreed that the layers represent the conceptual model (mean = 4), and all the healthcare providers strongly agreed with it (mean = 50). Two of the IT specialists strongly agreed with the representation of the six layers, and one of them agreed (mean =4.67), as shown in Figure 9.7. Therefore, the overall evaluation mean for the three groups was 4.56.

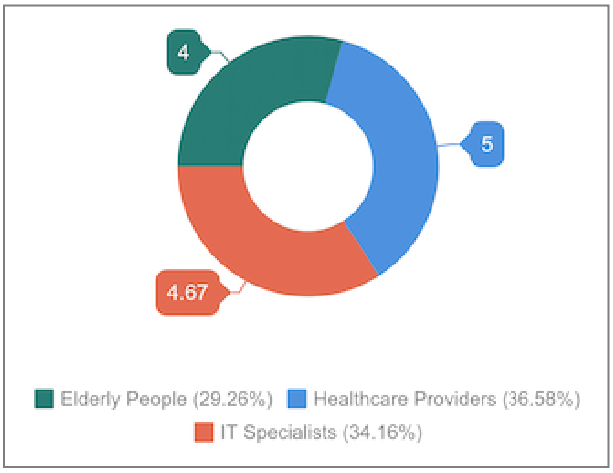


Figure 9.7: The Evaluation of the Six Layers Representation

➢ The conceptual model matches the real-world needs

In order to clarify this statement, an explanation about the processes of the conceptual model was presented. One elderly person strongly agreed, a second elderly person agreed, and the third elderly person chose neutral (mean = 4). Two of the healthcare providers and IT specialists agreed, and one of each group strongly agreed (mean for each group = 4.33), as presented in Figure 9.8. The overall evaluation mean for the three groups was 4.22.

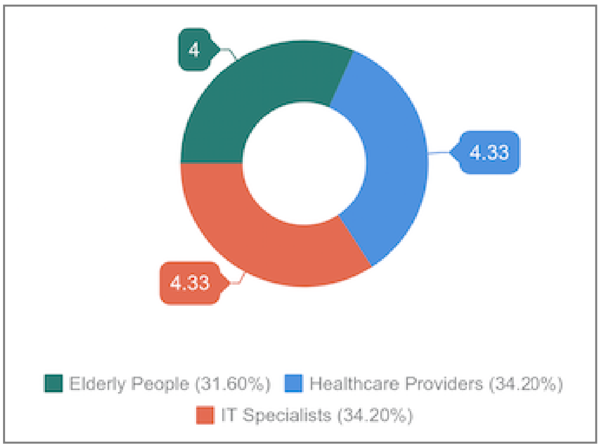


Figure 9.8: The Evaluation of Matching the Real World

➢ The conceptual model is intuitive to understand

The participants were asked if the conceptual model is intuitive to understand. The elderly people showed less understanding of the statement. Therefore, two of them were neutral, and one agreed (mean = 3.33). All the healthcare providers agreed with the statement (mean = 4), and two of the IT specialists agreed, while one strongly agreed that the conceptual model is intuitive to understand (mean = 4.33). The overall evaluation mean for this statement scored 3.89. Figure 9.9 illustrates the mean for each group.

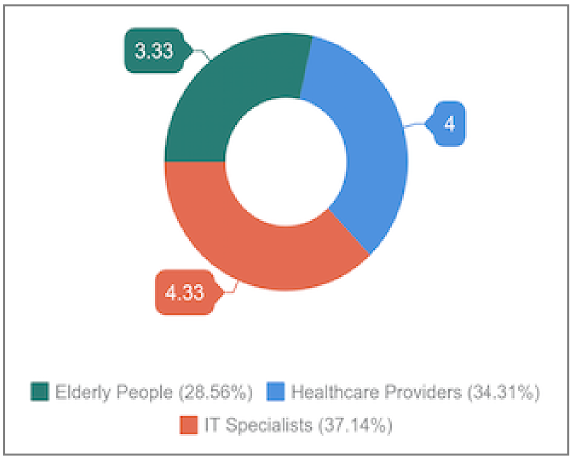


Figure 9.9: The Evaluation of Intuitive

➢ Overall Evaluation of the Conceptual Model

The overall evaluation mean of the conceptual model was 4.29, which is above average. This indicates that the conceptual model was accepted for use by the three groups, in order to provide elderly people with a better quality of life, and to allow them to live in their preferred environment, as shown in Figure 9.10 and Table 9.4.

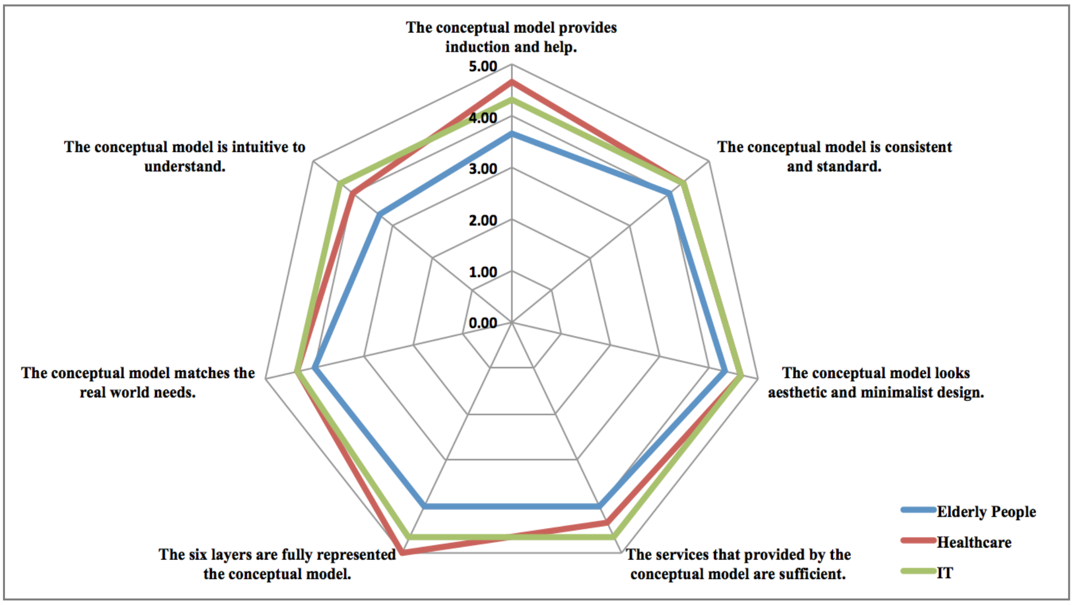


Figure 9.10: Overall Evaluation of the Conceptual Model

Table 9.4: Participants Evaluation for the Conceptual model by Each Group

Statements	Mean		
	Elderly People	Healthcare Providers	IT Specialists
The conceptual model provides induction and help.	3.67	4.67	4.33
The conceptual model is consistent and standard.	4.00	4.33	4.33
The conceptual model looks aesthetic and of minimalist design	4.33	4.67	4.67
The services provided by the conceptual model are sufficient.	4.00	4.33	4.67
The six layers of the conceptual model are fully represented	4.00	5.00	4.67
The conceptual model matches the real-world needs.	4.00	4.33	4.33
The conceptual model is intuitive to understand.	3.33	4.00	4.33
Overall Evaluation	**4.29**		

9.8.2: SECI Web Tools

The SECI model consists of four modes, which are socialisation, externalisation, combination and internalisation. Each mode is composed of a group of statements, and the mean for each group is counted separately, based on the evaluation by each participant.

- **Socialisation**

The web tools that are used to socialise tacit knowledge are social media, forums and wikis. One elderly person strongly agreed that social media could be used to share and communicate tacit knowledge, while two participants agreed. Thus, the mean for this group was 4.33. Two healthcare providers strongly agreed, and one agreed with the statement (mean = 6.67). All the IT specialist participants strongly agreed that social media could be an effective web tool to socialise the tacit knowledge (mean = 5).

The second web tool is a forum. All the elderly people agreed that forums can socialise knowledge related to AgeinginKSA (mean = 4). One of the healthcare providers strongly agreed, and two of them agreed (mean = 4.33). Two IT specialists strongly agreed with the statement and one agreed (mean = 4.67).

The third tool is the Community of Practice (CoP), which elicited less interest from the participants. Two of the elderly people chose neutral, and one agreed that CoP could be used as a web tool to socialise knowledge (mean = 3.33). Two of the healthcare providers agreed with the statements and one chose neutral (mean = 3.67). All the IT specialists agreed with the statement (mean = 4). Figure 9.11 shows the results for the web tools for the socialisation mode.

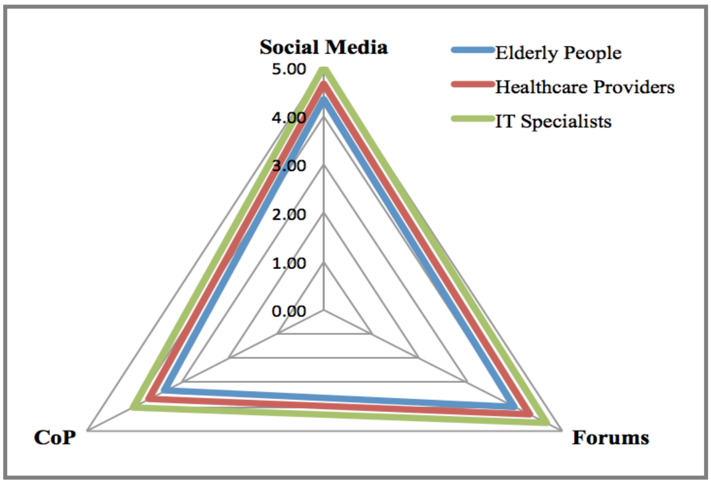


Figure 9.11: The Results of Socialisation Mode

➢ Externalisation

The web tools that are used to externalise tacit knowledge into explicit knowledge are wikis, blogs and forums. All the elderly people agreed that Wikis could be used as a tool to articulate and convert tacit knowledge into explicit knowledge, with mean = 4, while all the healthcare providers strongly agreed (mean=5), and all the IT specialist participants strongly agreed (mean=5).

The second web tool is a blog. Two of the elderly people agreed that blogs can support the externalisation process by providing opinions to everybody and offering a space to capture individual knowledge, and one strongly agreed, hence mean=4.33. Two of the healthcare providers agreed, and one of them strongly agreed with the statement (mean=4.33). All the IT specialists strongly agreed with the statement, with mean = 5.

The third tool is a forum. All the elderly people agreed that forums can be used to externalise tacit knowledge into explicit knowledge (mean = 4). Two of the healthcare providers agreed with the statement, and one chose neutral (mean = 3.67). All the IT specialists agreed with the statement with mean = 4.

Figure 9.12 illustrates the results of the web tools for the externalisation mode.

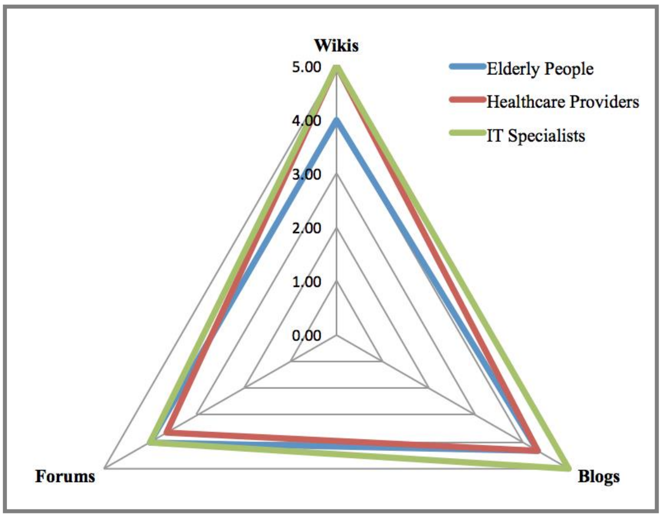


Figure 9.12: The Results of Externalisation Mode

➢ Combination

The web tools that are used to combine explicit knowledge with other explicit knowledge are documents and wikis. Two of the elderly people and two of the healthcare providers strongly agreed that a document is a form that provides the combination mode for exchanging and expressing explicit knowledge, and one of each group agreed (mean of each group = 4.67). Two of the IT specialists agreed with the statement, and one strongly agreed (mean = 4.33).

The second web tool is wiki. All the elderly people agreed that wiki could combine explicit knowledge by AgeinginKSA (mean = 4). Two of the healthcare providers agreed with the statement, and one strongly agreed (mean = 4.33). Two of the IT specialist participants strongly agreed, while one agreed with the statement, with mean = 4.67. Figure 9.13 shows the results of the web tools for the combination mode.

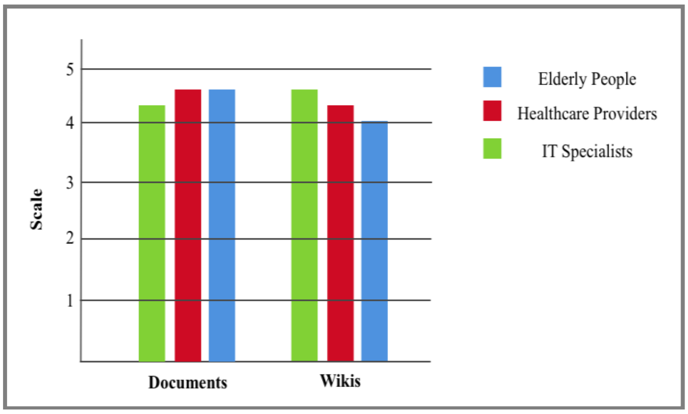


Figure 9.13: The Results of Combination Mode

➢ Internalisation

The web tools that are used to internalise the explicit knowledge into tacit knowledge are wikis, forums and CoPs. All the elderly people agreed that wikis can enable the internalisation process to produce more professional cooperative writing (mean = 4), while two of the healthcare providers strongly agreed and one agreed (mean=4.67). Two of the IT specialist participants agreed, and one strongly agreed with the statement (mean = 4.33).

The second web tool is a forum. Two of the elderly people agreed that forums can internalise knowledge, and one strongly agreed (mean=4.33). Two of the healthcare providers and of the IT specialists strongly agreed, and one of each group agreed with the statement (mean of each group = 4.67).

The third tool is a CoP. Two of the elderly people agreed that a CoP can be used to internalise explicit knowledge into tacit knowledge, and one disagreed (mean = 3.33). Two of the healthcare providers agreed about the statement and one chose neutral (mean = 3.67). Two of the IT specialists agreed, and one strongly agreed with the statement (mean = 4.33).

Figure 9.14 shows the results of the web tools for the internalisation mode.

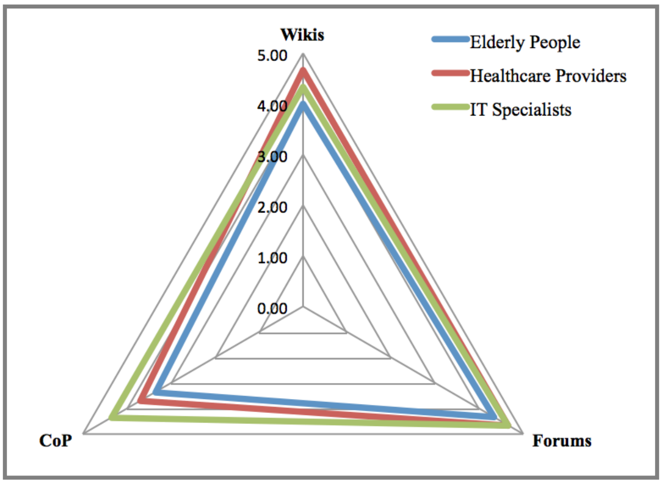


Figure 9.14: The Results of Internalisation Mode

➢ Overall Evaluation of the SECI Web Tools

According to the resulting mean for each mode, the combination mode scored the highest mean (4.44) of all the modes.

The second one was the externalisation mode with 4.37. The socialisation and internalisation came in third place equally, with mean = 4.22. The results showed that the participants mostly agreed that the web tools could be used to share and disseminate knowledge related to AgeinginKSA, as illustrated in

Figure 9.15. The overall mean = 4.31 for the four SECI modes indicates that the participations were satisfied with the web tools proposed for disseminating knowledge.

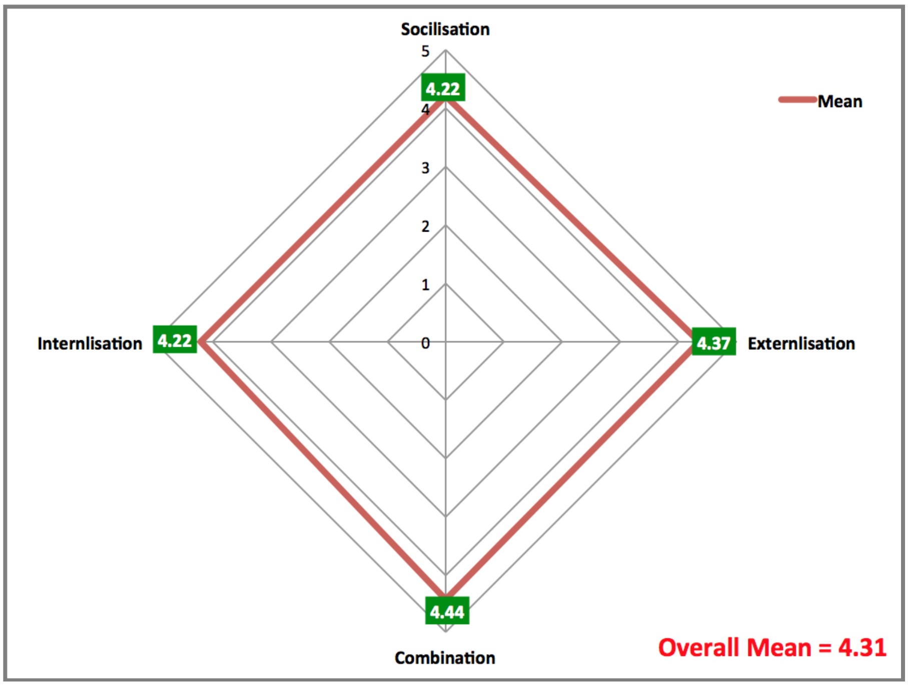


Figure 9.15: Over all Mean for All Four Modes

9.8.3: AgeinginKSA Evaluation

The same participants who were involved in evaluating the conceptual model and the SECI web tools participated in the evaluation of the AgeinginKSA website. The second part of the second session was the evaluation of AgeinginKSA, and the same technique was used. As mentioned in Section 9.3.1, we used the 10 guidelines for heuristic evaluation that were proposed by Nielsen (1995a). Therefore, the evaluation instrument consisted of 10 statements, chosen to evaluate AgeinginKSA and to identify usability problems, with the addition of an open-ended question, which was '*Are there any other suggestions that you would like to add?*'

- **Visibility of System Status**

The results showed that most of the participants indicated that there are no problems with the visibility of the system status. 89% of participants (8) indicated that AgeinginKSA can provide users working on the website with feedback within an appropriate time, while only one elderly person (11%) indicated that AgeinginKSA has a cosmetic problem related to visibility.

- **Match Between the System and the Real World**

Eight participants (89%) indicated that AgeinginKSA uses terms that are familiar to users, and that information appears logical and natural. This result emphasises that AgeinginKSA was designed to match the real world. Only one elderly person (11%) indicated that AgeinginKSA has a cosmetic problem related to this statement.

- **User Control and Freedom**

Eight participants (89%) reported that there are no issues with this factor, while one elderly person (11%) indicated that AgeinginKSA does not provide the user with freedom and control.

- **Consistency and Standards**

Eight participants (89%) reported that AgeinginKSA is built to be consistent and standardised, and it is easy to navigate. One elderly person (11%) indicated that AgeinginKSA has a cosmetic problem to be solved if possible.

- **Error Prevention**

This factor was evaluated positively by seven participants with (78%) and indicated that AgeinginKSA can address errors when they happen. However, 22% of participants (two elderly people) mentioned that there is a cosmetic problem.

- **Recognition Rather than Recall**

Eight participants (89%) reported that AgeinginKSA provides clear instructions on how to use every page, while 11% of participants (one elderly person) indicated it is missing some instructions and that changes should be made if time is available

- **Flexibility and Efficiency of Use**

Six of the participants (67%) indicated that AgeinginKSA can easily be used and no usability problems happened while exploring it. However, 33% of participants (two elderly people and one healthcare provider) reported that this factor has a minor problem.

- **Aesthetic and Minimalist Design**

All participants (100%) reported that AgeinginKSA demonstrates having relevant contents regarding the ageing population in the KSA and the AAL technologies that can be used to provide elderly people with a good quality of life and services they need.

➢ Help for Users to Recognise, Diagnose, and Recover from Errors

AgeinginKSA provides users with forms that allow them to register with the website, and once an error occurs it notifies users. Six participants (67%) indicated there is no usability problem with this factor, while two participants (22%) reported that there is a cosmetic problem. In addition, one participants (11%) stated there is a minor problem with this factor.

➢ Help and Documentation

Eight participants (89%) indicated that the AgeinginKSA provides help files and support forms, in order to make it easy to find answers to any questions. One elderly person suggested that this factor should be fixed if extra time is available (11%).

➢ Overall AgeinginKSA Evaluation

The overall evaluation for AgeinginKSA for the ten guidelines is 82%, which indicates there are no major problems with it. This indicates that AgeinginKSA has met the requirements of the stakeholders, which are elderly people, healthcare providers and IT specialists, and showed that they are satisfied with the design of AgeinginKSA and its contents, as shown in Figure 9.16.

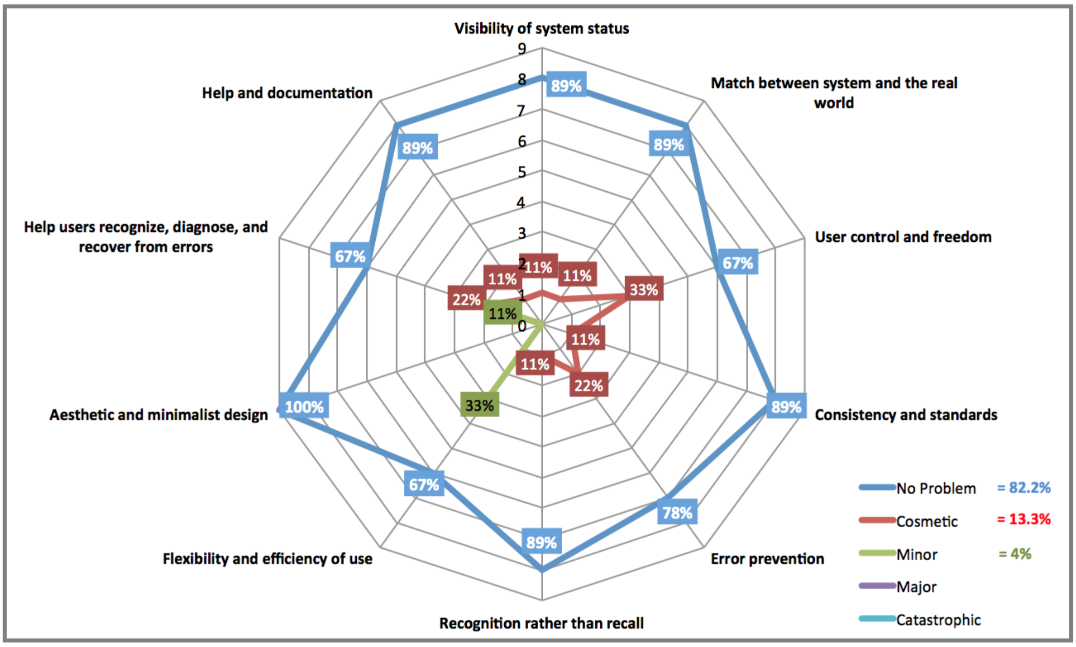


Figure 9.16: Overall AgeinginKSA Evaluation

- **Suggestions**

Seven of the participants suggested that a translation of AgeinginKSA into the Arabic language should be done immediately. Another suggestion was about adding a Saudi mobile number to the 'contact us' page. The final suggestion was about adding the Saudi 2030 vision logo and its link. The researcher studied these suggestions carefully in order to find out how valuable they were. Consequently, these three suggestions were accepted and met, as indicated in Section 8.7 (An Over View on AgeinginKSA Website).

9.9: Conclusion

This chapter discussed the development of instruments that are used to evaluate the conceptual model, SECI web tools to share knowledge, and AgeinginKSA website.

The analysis of the conceptual model's evaluation indicates that the conceptual model is accepted by the three stakeholder groups, with overall mean 4.29, as being suitable to provide elderly people with a better quality of life, and to allow them to live in their preferred environment. The analysis of the evaluation of SECI web tools indicated that:

- Tacit knowledge can be socialised via social media, forums and wikis
- Tacit knowledge can be externalised into explicit knowledge by using wikis, blogs and forums
- Explicit knowledge can be combined into explicit knowledge with documents and wikis
- Explicit knowledge can be internalised into tacit knowledge by wikis, forums and CoPs.

Furthermore, the analysis of the usability of the AgeinginKSA website indicated that the participants were satisfied, with overall evaluation 82%, about the design and contents, and they did not mention any major problems.

Chapter 10 discusses the conclusions of this thesis, identifying the limitations of the research and outlining the opportunities for future works.

Chapter 10: Conclusion and Future Work

10.1: Introduction

This chapter presents the conclusions of the research, focusing on its new theoretical and real-life operational systems, which accomplish its aims and objectives, centred on developing and implementing a new technology based model to provide a Home Proactive Monitoring System for elderly people in the KSA.

The chapter highlights the contributions and implications of the research and links them to the research aims. The limitations of the research are discussed, and the directions for future work are outlined.

10.2: The Context of the Research

Ageing populations are rapidly increasing worldwide, both in numbers and as a percentage of total population, and their care is already now and will be far more so in the future a growing challenge. The first part of the research (Chapter 2) reported on international statistics, and concluded that, globally, people aged over 60 numbered 901 million (12% of the world population) in 2015, but are expected to be 1.4 bn by 2030, 2.1 bn by 2050, and might increase to 3.2 billion in 2100 (United Nations, 2015d). the research found this problem to be much greater in the KSA.

The current status of elderly people in the KSA is controllable because their proportion is only 5%. However, this percentage will increase sharply to reach 20.9% in 2050, and is predicted to rise further to 33.5% by 2100 (Abusaaq, 2015; United Nations, 2015d; Al-shehri, 2012). The obvious conclusion is that the traditional, age old methods for caring for elderly people would impose enormous stresses on the human, medical, and financial resources of the country. It is clear that technological methods need to be devised and implemented to replace or complement the traditional methods. The aims and objectives of the research arose from this context.

10.3: The Aim and Objectives

The aim was to devise, design and implement a dependable self-adapting technological system that improves the quality of life for elderly people, provides them with technologies and services that support their daily activities, and helps them to live longer and to stay at home independently.

The aim was articulated into four sections:

a) Choosing an appropriate technology that could be used for implementing the many, different requirements of the aim
b) Ensuring that this technology would be accepted and applied by the potential users, surmounting the factors that very often lead new systems to be disregarded
c) Designing and implementing a system for the intelligent proactive monitoring of elderly people, which as well as collecting information, can interpret it and trigger appropriate actions whenever unusual patterns appear
d) Designing and implementing a website that can widely and easily spread information on the new system.

10.4: The Theoretical Choices and the New Real-life Operational Systems

a) The Ambient Assisted Living (AAL) technologies were selected, having been found to be the most suitable for our purposes. As shown in Chapter 3, Smart homes, assistive robotics, mobile and wearable sensors, and e-textiles are types of AAL technologies very useful to elderly people. The benefits are: independent living, assistance with daily activities, improved health, and being connected socially

b) The 'Decision Making Framework for the Adoption of AAL' (illustrated in Figure 4.6) was devised, designed and implemented by the research, and is the real-life framework recommended by this study for guiding and ensuring the adoption of AAL throughout the KSA. The AAL technologies are still largely unknown in the KSA, and their acceptance and adoption present major challenges. Therefore, it was considered vitally important to develop (Chapter 4) a holistic framework that facilitates the adoption and implementation of AAL throughout the KSA, for the support of stakeholders

c) A new 'AAL Home Proactive Monitoring System' AALHPMS, was devised, designed, implemented, and evaluated for real-life operation in the KSA, fulfilling the main purpose of the study. The system, however, is generally applicable and can also be used anywhere else

d) It was clear from the literature that heart rate is the simplest and best indicator of health status and the most reliable source of alarm signals for anything going wrong. There are many systems in operation for monitoring the heart rates of elderly people, but they usually produce information from which it is left to the monitoring carers to make diagnoses and decisions. We concluded that the purpose should be to create an intelligent proactive monitoring system that would automatically interpret the information and that would take appropriate action, when possible dangers were indicated, by contacting the monitored person, carers, doctors, police, etc

e) We considered that a Knowledge-Based System (KBS) could be used along with rule-based reasoning, for this new approach. The KBS would act as a decision support system that can make appropriate decisions and take action when an abnormal event occurs. A set of rules would be developed, according to the results from individual questionnaires and other information

f) A series of experiments (Chapter 6), which we carried out in the UK, the KSA and Germany, compared and contrasted the AAL tools available and concluded that Smart watches were the most suitable for the system. Another series of experiments (Chapter 7) determined the characteristics of systems that allow a combination of the detection of the heart rate and location of an aged person with communicating with him/her and/or summoning advice and help.

   All this theoretical and experimental work was concluded with the implementation of the new AAL Home Protective Monitoring System, AALHPMS, for real-life operation in the KSA

g) A new website AgeinginKSA, was specially designed and implemented to make the whole system developed by this research easily and widely accessible, particularly to aged people. This website will be available throughout the KSA.

   The concepts of the Knowledge Dissemination theory and the SECI web tools were applied to the design and implementation of this website (Chapter 8)

h) A full evaluation (Chapter 9) of the conceptual model, of the SECI web tools, and of the website was conducted. The findings on the fulfilment of the requirements by the conceptual model, the effectiveness of the SECI model, and the usability of the AgeinginKSA website, showed that the participants were satisfied with their design and contents, with a greater than 82 % overall approval level.

10.5: Contributions to Aims and Objectives

The main contributions of our research were:

- To recognise AAL as the best fit-for-purpose technologies for the support of aged people in the KSA
- To develop a “Decision Making Holistic Framework for the adoption of AAL” that supports elderly people, KSA healthcare providers, and decision makers in adopting AAL
- To develop a conceptual model using Ambient Assisted Living to provide a Home Proactive Monitoring System for elderly Saudi Arabians (AALHPMS).
- To design and implement a “Proactive Monitoring System” (PMS) that applies rule-based intelligence to monitor and assist proactively elderly people in their home
- A website was also designed to disseminate the relevant knowledge.

To the best of our knowledge, there are no studies that have investigated the use of AAL technologies in the KSA for addressing the ageing population’s challenges and issues in order to provide elderly people with a better quality of life and the ability to live independently.

The aim and objectives of this research have been accomplished, and their achievements were published in two papers in journals, five papers at conferences, and one chapter in a book. Table 10.1 shows the correlation between the chapters of this thesis and the objectives that have been achieved.

Table 10.1: Achievement of the Objectives

Objectives	Methods of Investigation	Chapter	Published
To carry out a literature review on the aging population, worldwide and in the KSA.	Academic papers and reports were reviewed in order to address the problems of ageing population in the KSA.	Ch. 2	✓
To carry out a literature review on the latest Ambient Assisted Living Technologies (ALL).	Academic papers and reports were reviewed in order to identify AAL technologies and to understand their concepts and benefits.	Ch. 3	✓
To carry out a literature review on the critical factors that affect the adoption and deployment in the KSA of Ambient Assisted Living Technologies.	A systematic review, using the PISMA method, was used in order to develop a decision making holistic framework for using AAL to support stakeholders	Ch. 4	✓
To conduct a survey in the Kingdom of Saudi Arabia to extract the elderly Saudi's attitudes and perceptions to using Ambient Assisted Living technologies, and to identity the factors that affect adoption of AAL technologies.	Quantitative strategy using a questionnaire in order to identify the factors that affect the adoption of AAL technologies by elderly people in the KSA.	Ch. 5	✓
To conduct a Community of Practice (CoP) with KSA healthcare providers in order to extract the factors that affect the adoption of AAL technologies	Qualitative strategy using a CoP in order to identify the factors that affect the adoption of AAL technologies by the healthcare providers in the KSA.	Ch. 5	✓
To conduct experimentations and to discuss their results.	Using Smart watches, ZigBee technology, Bluetooth beacons and cameras surveillance, in order to ensure these technologies are reliable and significant to be adopted.	Ch. 6	

To develop a conceptual model that supports the adoption of Ambient Assisted Living Technology in the KSA, with a specific focus on the elderly population, to provide a proactive monitoring system	20 studies were reviewed and analysed in order to develop a conceptual model for using Ambient Assisted Living to provide a Home Proactive Monitoring System for elderly People in the KSA (AALHPMS).	Ch. 7	✓
To design a knowledge-based system (KBS) with rule-based reasoning, to be developed as an important feature for the developed model.	Using Python to write a rule-based system	Ch. 8	✓
To design a web website for sharing and disseminating knowledge among people in the KSA.	Academic papers and reports were reviewed in order to: • Understand the Knowledge dissemination, SECI model and standards for designing websites. • Identify a web tool using SECI modes to share knowledge.	Ch. 8	
To evaluate the conceptual model, SECI web tools, and AgeinginKSA website	A Focus group, consisting of nine participants, in order to get useful feedback and help to improve the works.	Ch. 9	

10.6: Research Limitations

The contributions of this Ph.D research have provided valuable implications and insights for elderly people, healthcare providers and decision makers. However, this research has identified some limitations as follow:

i. Three categories of participants, which were elderly people, healthcare providers and IT specialists, participated in the evaluation of the SECI web tools. It would have been better to have a fourth category of knowledge experts, in order to cover all related concepts

ii. The beacon Bluetooth experiment required that the elderly person should carry a mobile. Therefore, more investigations are required to find a Smart watch that can be used to directly connect to the Bluetooth, instead of a mobile

iii. The sample size for the questionnaire for elderly people was 194 participants, and further focus group would have been useful to enrich the information, but not practical because of the time limits of the research

iv. The lack of elderly people life style information that can be found and studied in the literature was an issue. This made it difficult to collect information about their lives, health, living status, total numbers, culture and communication

v. It would be useful to have a available wider selection of medically approved Smart watches for measuring heart rates for comparison and reliability testing

vi. The scope of this research was broad considering the time that was assigned to complete it.

10.7: Future Work

This research has focused on the development of a conceptual model that assists elderly people, healthcare providers and decision makers in the KSA, in order to adopt AAL technologies. Therefore, the discussion in this research has also opened up more areas to be investigated for future work as follows:

i. AAL technologies are still largely unknown in the KSA. Therefore, these technologies could be made more widely known by establishing a laboratory at Shaqra University and calling it Ambient Assisted Living (AAL), in order to implement the model AALHPMS that was developed in this research. This laboratory could include an apartment that has the technologies that were used in this research and could host an elderly person. Then this work could be shared in collaboration with the Ministry of Labour and Social Development, which is responsible for social care homes in the KSA, in order to implement the model at one of the social care homes

ii. The scope of this research is dedicated to elderly people. However, it is open ended and relevant for investigations and studies applicable to other people who are not less important than elderly people. The research and its results would be directly relevant to people who need care and monitoring while at home, and particularly to provide support for disabled people in the KSA

iii. The aim of this research was to develop a conceptual model to provide elderly people with a proactive monitoring system at home. However, the model could be expanded to monitor elderly people when they are outside. This may require investigating the technologies that can be used outdoors, such as for tracking people while they are outside their home

iv. The rule-based system that was coded in this research was just for monitoring heart rate and was not in real time. Therefore, a more sophisticated rule-based system based on the requirements of elderly people could be coded and integrated with what was proposed for future work

v. It is critical to take action when abnormalities occur. Therefore, it is important to identify the thresholds that determine the type of action that is tailored to a specific issue. This requires investigating the cases and issues that have happened to elderly people, and integrating this with the knowledge-reasoning layer

vi. AALHPMS was developed for elderly Saudi Arabians since the Saudi population is ageing. Khan et al. (2017) indicated that the Gulf countries are also ageing because of their demographic changes. Therefore, the developed conceptual model could be suitable for application in other Gulf countries, which have a similar culture

vii. A Virtual Active Ageing Community (VAAC) could be deigned to provide the elderly people with a web tool that can help them to be connected and socialised with other form different districts, cities and regions as illustrated in Figure 10.1.

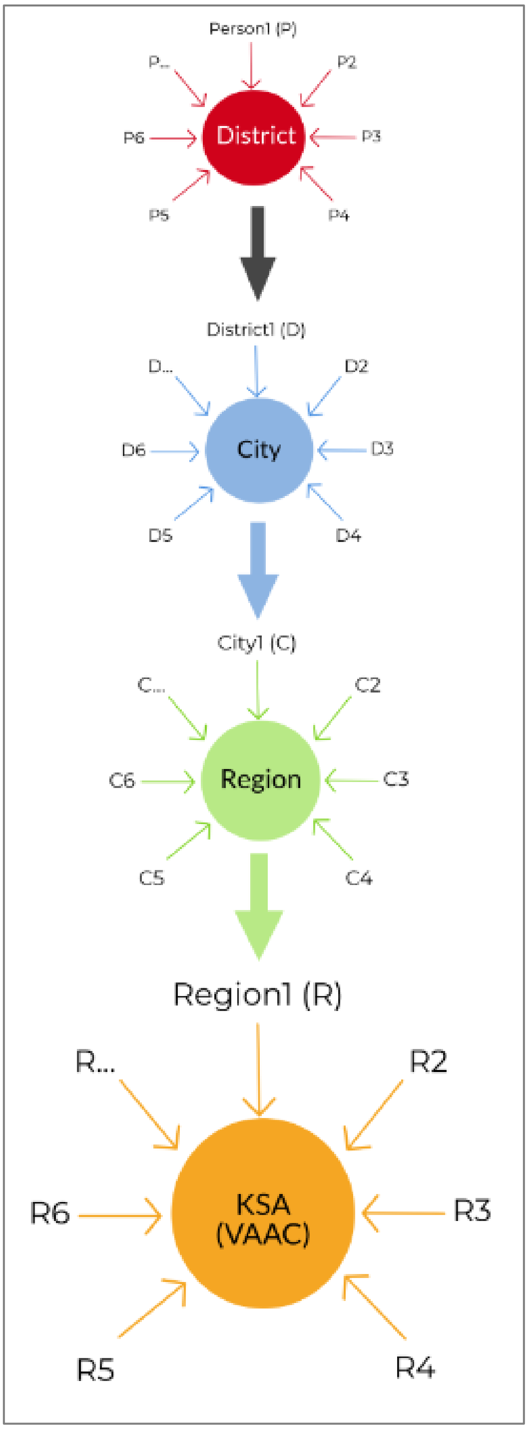


Figure 10.1: The Proposed VAAC

Finally, I feel that the real-life application in the KSA of the systems developed by this study will show clear tangible benefits to elderly people and to the provision of health facilities, and I hope this will set a good early example to encourage the massive introduction of new technology, necessary to cope with the coming surge in the size of the KSA's elderly population.

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Appendix 1: Ethical Form

RESEARCH ETHICS

Proportionate Review Form

STAFFORDSHIRE UNIVERSITY

The Proportionate Review process may be used where the proposed research raises only minimal ethical risk. This research must: focus on minimally sensitive topics; entail minimal intrusion or disruption to others; and involve participants who would not be considered vulnerable in the context of the research.

PART A: TO BE COMPLETED BY RESEARCHER

Name of Researcher:	Majid Alsulami

Student/Course Details (If Applicable)			
Student ID Number:			14025869
Name of Supervisor(s)/Module Tutor:			Principal Supervisor: Prof. Bernadette Sharp Second Supervisor: Prof. Anthony Atkins
PhD/MPhil project:	☒		
Taught Postgraduate Project/Assignment:	☐	Award Title:	PhD
Undergraduate Project/Assignment:	☐	Module Title:	

Project Title:	Ambient Assisted Living Technology (AALT)		
Project Outline:	1. To carry out a literature review on i. The Aging Population particularly in KSA ii. The latest Ambient Assisted Living Technology (AALT) iii. The critical factors that impact on deploying Ambient Assisted Living Technology (AALT) in KSA 2. To develop a strategic framework that supports the adoption of Ambient Assisted Living Technology (AALT) in the Kingdom of Saudi Arabia (KSA), with a specific focus on elderly 3. To conduct a survey in the Kingdom of Saudi Arabia to evaluate: • The readiness to implement Ambient Assisted Living Technology (AALT) in KSA • The challenges and barriers that restrict the adoption and implementation of AALT • The elderly's culture attitude towards using Ambient Assisted Living Technology (AALT) 4. To test, validate and evaluate the proposed framework by using information from literature review to provide study evaluation criteria together with a case study in KSA.		
Give a brief description of participants and procedure (methods, tests etc.)	An online questionnaire will be publisehd and email atachments will be sent		
Expected Start Date:	24/10/14	Expected End Date:	30/12/17

Relevant professional body ethical guidelines should be consulted when completing this form.

Please seek guidance from the Chair of your Faculty Research Ethics Committee if you are uncertain about any ethical issues arising from this application.

There is an obligation on the researcher and supervisor (where applicable) to bring to the attention of the Faculty Ethics Committee any issues with ethical implications not identified by this form.

Researcher Declaration

I consider that this project has no significant ethical implications requiring full ethical review by the Faculty Research Ethics Committee.	☒

I confirm that:		
1.	The research will **NOT** involve members of vulnerable groups. Vulnerable groups include but are not limited to: children and young people (under 18 years of age), those with a learning disability or cognitive impairment, patients, people in custody, people engaged in illegal activities (e.g. drug taking), or individuals in a dependent or unequal relationship.	☒
2.	The research will **NOT** involve sensitive topics. Sensitive topics include, but are not limited to: participants' sexual behaviour, their illegal or political behaviour, their experience of violence, their abuse or exploitation, their mental health, their gender or ethnic status. The research must not involve groups where permission of a gatekeeper is normally required for initial access to members, for example, ethnic or cultural groups, native peoples or indigenous communities.	☒
3.	The research will **NOT** deliberately mislead participants in any way.	☒
4.	The research will **NOT** involve access to records of personal or confidential information, including genetic or other biological information, concerning identifiable individuals.	☒
5.	The research will **NOT** induce psychological stress, anxiety or humiliation, cause more than minimal pain, or involve intrusive interventions. This includes, but is not limited to: the administration of drugs or other substances, vigorous physical exercise, or techniques such as hypnotherapy which may cause participants to reveal information which could cause concern, in the course of their everyday life.	☒
6.	The research **WILL** be conducted with participants' full and informed consent at the time the study is carried out: • The main procedure will be explained to participants in advance, so that they are informed about what to expect. ☒ • Participants will be told their involvement in the research is voluntary. ☒ • Written consent will be obtained from participants. *(This is not required for self-completion questionnaires as submission of the completed questionnaire implies consent to participate).* ☐ • Participants will be informed about how they may withdraw from the research at any time and for any reason. ☒ • For questionnaires and interviews: Participants will be given the option of omitting questions they do not want to answer. ☒ • Participants will be told that their data will be treated with full confidentiality and that, if published, every effort will be made to ensure it will not be identifiable as theirs. ☒ • Participants will be given the opportunity to be debriefed i.e. to find out more about the study and its results. ☒	☒ N/A ☐

If you are unable to confirm any of the above statements, please complete a **Full Ethical Review Form**. If the research will include participants that are **patients**, please complete the Independent Peer Review process.

Supporting Documentation

All key documents e.g. consent form, information sheet, questionnaire/interview schedule are appended to this application.	☒

Signature of Researcher:	[signature]	Date:	18/6/15

NB: If the research departs from the protocol which provides the basis for this proportionate review, then further review will be required and the applicant and supervisor(s) should consider whether or not the proportionate review remains appropriate. If it is no longer appropriate a full ethical review form **MUST** be submitted for consideration by the Faculty Research Ethics Committee.

Next Step:

STUDENTS: Please submit this form (and supporting documentation) for consideration by your Supervisor/ Module Tutor.

STAFF: Please forward this form to the Chair of Faculty Research Ethics Committee who will arrange for it to be considered by an independent member of the Faculty Research Ethics Committee.

PART B: TO BE COMPLETED BY SUPERVISOR/MODULE TUTOR (If Applicable)

I consider that this project has no significant ethical implications requiring full ethical review by the Faculty Research Ethics Committee.	☑
I have checked and approved the key documents required for this proposal (e.g. consent form, information sheet, questionnaire, interview schedule).	☑

Signature of Supervisor:	[signature]	Date:	18/6/15

Next Step: Please forward this form to the Chair of Faculty Research Ethics Committee who will arrange for it to be considered by an independent member of the Faculty Research Ethics Committee, having no direct connection with the researcher or his/her programme of study.

PART C: TO BE COMPLETED BY FACULTY RESEARCH ETHICS COMMITTEE MEMBER

This research proposal has been considered using agreed University Procedures and is now approved. **Or** This research proposal has not been approved due to the reasons given below.	☑ ☐

Name of Reviewer:	Elhadj Benkhelifa	Date:	19/06/2015
Signature:	[signature]		

Proportionate Review

Appendix 2: Questionnaire

Dear Sir / Madam

Ambient assisted living (AAL) promises to play a prominent role in providing the independence and quality of life for elderly people, senior citizen. Despite the benefits that are delivered by AALT, there are some factors affecting the adoption of AALT. One of the challenges that face the deployment is the technologies acceptance. This questionnaire will extract attitudes and perceptions of elderly people, whose age over 60 years, towards using AAL Technologies (AALT). The results of the questionnaire will find out the level of acceptance of the use of Ambient Assisted Living Technology (AALT) in Kingdom of Saudi Arabia (KSA) by investigating the elderly opinions.

المساعدات المحيطة بالحياة (AAL) تلعب دوراً بارزاً في توفير الاستقلال ونوعية الحياة لكبار السن، على الرغم من الفوائد التي يتم توفيرها من قبل التقنيات المساعدة المحيطة بالحياة، هناك بعض العوامل التي تساهم في تبنيها. واحدة من العوامل التي تواجه تبني هذه التقنيات هو قبول استخدامها من قبل كبار السن. وهذا الاستبيان يهدف الى معرفة مواقف وتصورات كبار السن، الذين بلغت أعمارهم أكثر من 60 عاما في المملكة العربية السعودية(KSA) ، نحو استخدام هذه التقنيات. وسوف ينتج عن هذا الاستبيان معرفة مستوى قبول استخدام هذه التقنيات في المملكة العربية السعودية (KSA).

This questionnaire is a part of a PhD degree being started at Staffordshire University in the United Kingdom (UK).

هذا الاستبيان هو أحد متطلبات نيل درجة الدكتوراه من جامعة ستافوردشاير في المملكة المتحدة.

Please remember that:

- **DO NOT** participate in this questionnaire if you are vulnerable to constraint or inappropriate influence (e.g.,, unable to agree, under 18 years, prisoner, etc.)
- The main procedures will be described to participants in advance, so that they are informed about what to expect
- All responses will be confident, and names of participants are not required and that, if published, it will not be identifiable as theirs
- Cooperating to respond to every question, will help us understand important questions with regards to AAL acceptance, however you are not required to respond every question

- Your participation in this questionnaire is voluntary
- The participants have the right to withdraw from the research at any time and for any reason
- There are no direct benefits to you for participating in this research.
- There are no risks associated with participation
- The participants must be willing to be debriefed e.g., to find out more about the study and its results
- This questionnaire is available in two languages (Arabic and English).
- By selecting 'Next' button, you acknowledge that you agree to participate in this questionnaire.

نأمل ملاحظة التالي:

- لا تشارك في هذا الاستبيان إذا كنت عرضة للإكراه او مجبر على المشاركة (على سبيل المثال، غير قادر على الموافقة، عمرك أقل من 18 عاما، سجين، وما إلى ذلك)
- سيتم وصف الإجراءات الرئيسية للمشاركين في وقت مبكر، بحيث يتم إبلاغهم عما يمكن توقعه
- سيتم التعامل مع جميع الأراء بسرية وخصوصية تامة كما انه ليس مطلوب من المشاركين الإدلاء بمعلوماتهم الشخصية كالأسماء
- من مبدأ التعاون، الإجابة على كل سؤال سوف يثري الاستبيان لمعرفة مدى قبول التقنية للمسنين، ومع ذلك لست ملزما بالرد على كل سؤال
- المشاركة في هذا الاستبيان تطوع
- يحق لك الانسحاب من الاستبيان في أي وقت ولأي سبب من الأسباب
- لا توجد فوائد مباشرة لك في المشاركة في هذا البحث
- لا توجد مخاطر في حالة المشاركة من عدمها
- المشاركون يحق لهم الاستفسار لمعرفة المزيد عن هذه الدراسة ونتائجها
- هذا الاستبيان متاح باللغتين (العربية والإنجليزية)
- عند اختيار زر "التالي"، فإنك توافق على المشاركة في هذا الاستبيان.

☐ Agree (موافق)

☐ Disagree (غير موافق)

If you have any questions regard the questionnaire, kindly, contact the researcher:

إذا كان لديك أي أسئلة عن هذا الاستبيان، فيمكنك التواصل مع الباحث:

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Ambient Assisted Living (AAL): "relates to intelligent systems of assistance for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment, with the aim of enhancing the quality of life for all elderly people in all stages of their life" (AALIANCE, 2009, vii).

المساعدات المحيطة بالحياة (AAL) تتعلق بالأنظمة الذكية المساعدة التي توفر حياة أفضل وصحية وأكثر أمانا في المسكن الذي يرغب الأشخاص العيش به، وهي تغطي المفاهيم والمنتجات والخدمات التي تربط بين التكنولوجيات الجديدة والبيئة الاجتماعية، وذلك بهدف تحسين نوعية الحياة لجميع المسنين في جميع مراحل حياتهم (اليانز, 2009, صحفة 7).

Part I: Participant Details for the person receiving care:

الجزء الأول: معلومات المشارك الذي سوف يتلقى الرعاية:

Q1: Gender: (الجنس)
☐Male (1) (ذكر)
☐Female (2) (انثى)

Q2: Age Group: (الفئة العمري)
☐60- 69 (1)
☐70 – 79 (2)
☐80+ (3)

Q3: Nationality: الرجاء تحديد جنسيتك؟
☐Saudi (1) (سعودي)
☐Non-Saudi (2) (غير سعودي)

Q4: What is your current living statues? الرجاء تحديد مع من تسكن؟
☐Living alone (1) بمفردي
☐Living with family members (2) مع احد افراد العائلة
☐Living with relatives (3) مع اقاربي
☐Living with friends (4) مع اصدقائي
☐Living in social care home (5) في دور الرعاية الاجتماعية

☐Other, please specify: (6) ____________________ أخرى

Part II: Culture and Social Interaction:

الجزء الثاني: الثقافة والتفاعل الاجتماعي:

Q5: Which kinds of assistance are you receiving in your daily living?

الرجاء تحديد أي من المساعدات التالية تقدمها لك عائلتك؟

You can tick more than one option. يمكنك تحديد أكثر من خيار

Shopping (1) التسوق

☐Dressing (2) الملبس

☐Eating (3) الأكل

☐Washing (4) الغسيل

☐Cleaning (5) التنظيف

☐Cooking (6) الطبخ

☐Bedding (7) النوم

☐Toileting (8) الذهاب لدورات المياه

☐Bathing (9) الاستحمام

☐Walking Upstairs (10) طلوع الدور العلوي

☐Walking Downstairs (11) نزول للدور السفلي

☐None (13) لاشي

☐Other, please specify: (12) ____________________ اخرى, الرجاء التحديد

Q6: Which of the following social networks do you use to connect your families, relatives, friends, etc.? You can tick more than one option.

الرجاء تحديد أي من وسائل التواصل الاجتماعي التالية تستخدم للتواصل بعائلتك، اقاربك، اصدقائك وغيرهم؟ يمكنك تحديد أكثر من خيار.

☐Facebook (1) الفيس بوك

☐Twitter (2) توتير

☐Skype (3) سكايبي

☐SMS (4) الرسائل النصية

☐YouTube (5) اليوتيوب

☐None (6)

☐Other, please specify: (7) ____________________اخرى, الرجاء التحديد

Part III: Home, Concerns and Factors:

الجزء الثالث: المنزل، الاهتمامات والعوامل:

Q7: Is your home equipped with the following communications facilities?

هل منزلك مجهز بأجهزة الاتصالات التالية؟

	Yes (1) نعم	No (2) لا
Internet (1) الإنترنت		
Camera surveillance (2) المراقبة باستخدام الكاميرا		
Camera with video recording (3) كاميرا مع تسجيل فيديوا		

Q8: Would you be amenable to install the following sensors in your home if they were available?

هل توافق على تثبيت أجهزة الاستشعار في منزلك التالية؟

	Yes (1)نعم	No (2) لا
Bed Sensor (1) سرير الاستشعار		
Motion Sensor (2) استشعار الحرك		
Temperature Sensor (3) استشعار درجة الحرارة		

Q9: Would you be concerned about any of the following?

ما هو مدى قلقك تجاه المواضيع التالية؟

	Very Unconcerned (1) غير قلق جدا	Unconcerned (2) غير قلق	Neutral (3) محايد	Concerned (4) قلق	Very Concerned (5) قلق جدا
Individual Privacy (1) الخصوصية					
Personal Data (2)					

البيانات الشخصية					
Personal Health Status (4) حالتك الصحية					

Q10: How important are the following aspects to you?

ما مدى أهمية المواضيع التالية بالنسبة لك؟

	Very Unimportant (1) جدا غير مهم	Unimportant (2) غير مهم	Neutral (3) محايد	Important (4) مهم	Very Important (5) جدا مهم
Home Security (1) أمن المنزل					
Home Safety (2) السلامة في المنزل					
Usability of Technology (3) استخدام التقنية					
Size intrusion of technological Devices (4) حجم الأجهزة					
Weigh intrusion of technological Devices (5) وزن الأجهزة					

Part IV: AAL Technologies:

الجزء الرابع :التقنيات المساندة المحيطة بحياتنا:

Q11: Which of the following technologies do you use?

الرجاء تحديد أي من التقنيات التالية تستخدم؟You can tick more than one option.

☐Personal Computer / Laptop (1) (جهاز محمول /حاسب شخصي)

☐Internet / Email (2) (الإنترنت /بريد إلكتروني)

☐Smart Devices (e.g., mobile, iPad, etc.) (3) (الأجهزة الذكية كالجوال والإيباد)

☐None (4) (لا شي)

☐Other, please specify: (5) ____________________ أخرى

Q12: Would you like to have technology that switches off appliances automatically when not in use (e.g., Heater, Microwave, Stove, etc.)?

هل ترغب في الحصول على التقنية التي تتوقف عن العمل عند عدم الاستخدام تلقائيا (مثل: السخان، الميكروويف، البتقاز، وغيرها)؟

☐Yes (1) نعم

☐No (2) لا

Q13: Would you be agreeable to allow professional carers to see your daily activities data?

إلى أي مدى توافق للسماح لمقدمي الرعاية المهنية للاطلاع على البيانات الخاصة بأنشطتك اليومية؟

☐Strongly Disagree (1) لا أوافق بشدة

☐Disagree (2) لا أوافق

☐Neutral (3) محايد

☐Agree (4) أوافق

☐Strongly Agree (5) أوافق بشدة

Q14: Would you be agreeable to allow professional carers to use cameras to monitor your activities?

إلى أي مدى توافق للسماح لمقدمي الرعاية المهنية بمتابعتك باستخدام الكاميرا؟

☐Strongly Disagree (1) لا أوافق بشدة

☐Disagree (2) لا أوافق

☐Neutral (3) محايد

☐Agree (4) أوافق

☐Strongly Agree (5) أوافق بشدة

Q15: In the case of emergency (e.g., where sensor technology as indicated that you have fallen, etc.), would you be agreeable to turn on a camera for professional carers to check on your safety?

في حالة الطواري (مثال: عندما تلاحظ تقنية الاستشعار سقوطك) إلى أي مدى توافق للسماح لمقدمي الرعاية المهنية لتشغيل الكاميرا للاطمئنان على سلامتك؟

☐Strongly Disagree (1) لا أوافق بشدة

☐Disagree (2) لا أوافق

☐Neutral (3) محايد

☐Agree (4) أوافق

☐Strongly Agree (5) أوافق بشدة

Q16: Would you be agreeable to using the following AAL technologies?

إلى أي مدى توافق على استخدام التقنيات التالية؟

	Strongly Disagree (1) لا أوافق بشدة	Disagree (2) لا أوافق	Neutral (3) محايد	Agree (4) أوافق	Strongly Agree (5) أوافق بشدة
Smart homes (1) (e.g., Camera) المنازل الذكية (مثل الكاميرا) It provides facilities to home care for elderly people in an encouraging and cost-effective manner. توفر مرافق للرعاية المنزلية للمسنين بطريقة مشجعة وفعالة من حيث التكلفة.					
Assistive robotics (2) (e.g., Vacuum) الروبوتات المساعدة)مثل المكنسة كهربائية(It is a tool that assists and supports users to do their activities in homes. تعتبر وسيلة تساعد وتدعم المستخدمين للقيام بأنشطتهم في					

المنازل.					
Mobile devices (3) (e.g., Tacking system) الأجهزة المحمولة (مثل أنظمة المتابعة) Mobile system is an application that monitors users' status. It is a terminal device that has an application installed to connect with a tele-monitoring service remotely. النظام المحمول هو تطبيق يستخدم لمراقبة حالة المستخدمين. وهو عبارة عن جهاز طرفي يحتوي على تطبيق مثبت لتقديم خدمة عن بعد.					
e-textile (4) (e.g., T-Shirt) المنسوجات (مثل القمصان) The main idea of smart textile is to design textile with smart accessories and computing power to assist its users. الفكرة الرئيسية من المنسوجات الذكية هي تصميم المنسوجات مع الملحقات الذكية والقدرة الحاسوبية لمساعدة مستخدميها.					
Wearable sensors (5) (e.g., Watch) أجهزة استشعار يمكن ارتداؤها (مثل ساعة اليد) Wearable systems are designed to be worn throughout regular day-to-day activities.					

Wearable sensors can be attached into clothing and jewelry, or accessories such as torso belts, gloves, harnesses or arm, forearm and wrist bands. تم تصميم أنظمة يمكن ارتداؤها خلال الأنشطة اليومية. حيث يمكن ارتداء أجهزة الاستشعار في الملابس والمجوهرات أو الاكسسوارات مثل ألإحزمة، والقفازات، وغيرها.					

Q17: Would you like to have a technology that has warning systems to remind you to take a medicine, drink, food, sleep, etc.?

هل ترغب في الحصول على تقنيات تحتوي على أنظمة للتذكيرك بوقت أخذ الدواء والشرب والأكل والنوم، وغيرها؟

Yes (1) نعم

No (2) لا

Q18: Would you like to have a technology that contacts your care provider when needed immediately by just pressing a button?

هل ترغب في الحصول على تقنية تقوم بالاتصال بمزود الخدمة عند الحاجة باستخدام فقط ضغطة زر؟

☐Yes (1) نعم

☐No (2) لا

Q19: Would you like to be trained on using technologies such as computer, social networks, email, etc.?

هل لديك الرغبة للتدريب على استخدام تقنيات مثل الكمبيوتر والشبكات الاجتماعية والبريد الإلكتروني، وغيرها؟

☐Yes (1) نعم

☐No (2) لا

Q20: How would you like to be assisted in your daily living?

في حياتك اليومية، إلى أي مدى تفضل ان تقدم لك المساعدة بالطرق التالية؟

	Strongly Dislike (1) لا أوافق بشد	Dislike (2) لا أوافق	Neutral (3) محايد	Like (4) أوافق	Strongly Like (5) أوافق بشد
By human interaction (1) عن طريق التفاعل البشري					
By technology Communications (2) عن طريق التواصل التقني					

Part V: Professional carers:

الجزء الخامس: مقدم الرعاية المهنية:

Q21 How would you like to be seen by professional carers?

إلى أي مدى ترغب بمقابلة مقدمي الرعاية المهنية بأحد الطرق التالية؟

	Strongly Dislike (1) لا ارغب بشدة	Dislike (2) لا ارغب	Neutral (3) محايد	Like (4) ارغب	Strongly Like (5) ارغب بشدة
By visiting (1) عن طريق الزيارات					
By using AALT (2) عن طريق استخدام التقنيات المساندة المحيطة بحياتنا					

Q22 If visited. في حالة الزيارة

How often would you like to be visited?

ماهي عدد الزيارات التي ترغب بها؟

☐Daily (1) يومي

☐Weekly (2) اسبوعي

☐Monthly (3) شهري

- Part VI: Open-ended Questions.

الجزء السادس: الاسئلة العامة:

Q23: Do you have any suggestions for assisting you in your daily activities?

هل لديك أي اقتراحات بشأن تقديم مساعدات لك في الأنشطة اليومية الخاصة بك؟

Q24: Are there any other factors that would affect your decision to use AALT?

برأيك، ما هي العوامل الأخرى التي يمكن أن تؤثر على قرارتك لاستخدام التقنيات المساعدة المحيطة بالحياة؟

End of Questionnaire…

نهاية الاستبيان...

Thank you for your participation… We appreciate your effort.

أشكركم على مشاركتكم ... وأقدر جهدكم.

Majid Alsulami: PhD researcher, Staffordshire University, Shaqra University

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