Sensor-based monitoring for enhancing patient care in a developing country in South-East Europe

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Abstract

Background and aim: In recent years, the number of patients diagnosed with chronic illnesses has increased, especially in developing countries. The continuous and remote monitoring of chronic parameters is considered to improve patient care and provide information for the early diagnosis, treatment, and management of these long-term conditions. In this regard, this research investigated the adoption and acceptance of sensor-based platforms for remote and continuous monitoring of chronically ill patients. The aim was to address the lack of knowledge on the implementation and application of sensor-based platforms among healthcare professionals (HCP) in Kosovo, a developing country in South-East Europe (SEE).

Methods: A qualitative research method was used, in which HCPs from a private hospital were interviewed in Kosovo. Two semi-structured in-depth interview studies were developed based on technology acceptance variables. Hence, the first interview study investigated the adoption and acceptance of sensor-based platforms for remote and continuous patient monitoring among HCPs. Findings from this interview study enabled the design and proposal of a sensor-based prototype which was evaluated during the second interview study to elaborate the HCPs' experiences and feedback with the functionalities that provided real-time and distance-based monitoring of vital signs and communication with their patients.

Findings: The first interview study with HCPs provided a detailed understanding of their current practices with digital monitoring systems and suggested aspects on the needs for real-time and continuous monitoring. Truth-telling emerged as a new technology acceptance variable from this study: this was considered important to investigate when designing and implementing digital technologies for healthcare that include the patient's access. This interview study provided also recommendations for designing and implementing the proposed sensor-based prototype, SBNHealth. The evaluation interview study revealed more specific details towards the successful implementation of sensor-based platforms in this developing country, Kosovo. Hence, the findings suggested that there should be a managerial willingness from the healthcare institutions and a close collaboration between the monitoring medical staff and the patient to enable accurate and safe communication that will lead to improved healthcare services and patient wellbeing.

Conclusions: This research contributed to a set of measures and interventions proposed for future designers and implementers (i.e., industry), users (healthcare professionals and patients), and managers and policymakers (i.e., government, healthcare institutions), from the healthcare practices and needs of Kosovo, concerning successful implementation and application of sensor-based platforms. Building upon technology acceptance theories, to understand the adoption and acceptance of digital platforms, this study has implications on the practices of HCPs (improved and digitalized healthcare services), patient care (continuous and real-time monitoring), healthcare centres (manage better the increased number of chronically ill patients, lower rates of hospitalization, fewer resources in use) and, in this way, also on the healthcare system of a developing country (enhanced life expectancy). Further to these, is also the scientific contribution by providing two investigations with unique field results on a research area where there is limited information.

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List of abbreviations and acronyms

*Explanation with an asterisk (*) indicate that they have been translated from Albanian

Abbreviation	**Explanation**
ADC	Analogue to Digital Converter
ADSL	Asymmetric digital subscriber lines
AMON	The Advanced Medical Monitor
API	Application Programming Interface
ARKEP	Regulatory Authority of Electronic and Postal Communications of Kosovo*
ASK	Statistical Agency of Kosovo*
CGM	Continuous Glucose Monitoring
COPD	Chronic Obstructive Pulmonary Disease
CSS	Cascading Style Sheets
DESI	Digital Economic Society Index
ECG	Electrocardiography
EHR	Electronic health record
FDA	Food and Drug Agency
FITT	Fit between individuals, task and technology
GDP	Gross Domestic Product
GNI	Gross National Income
GRA	Graduate Research Assistant
GSM	Global System for Mobile Communications
HDI	Human Development Index
HF	Heart Failure
HCP	Healthcare professionals
HR	Human resources department
HTML	Hypertext Markup Language
ICT	Information and communication technology
IoT	Internet of things
IPA	Interpretative Phenomenological Analysis
ISP	Internet Service Provider
LTE	Long-Term Evolution
PE	Performance expectancy (technology acceptance concept)
PEOU	Perceived ease of use (technology acceptance concept)
PPG	Photoplethysmography
PU	Perceived usefulness (technology acceptance concept)
RGB	Red, green, and blue
RPM	Remote Patient Monitoring
SBN	Sensor-based networks
SBNHealth	Sensor-based health monitoring prototype proposed in this thesis
SDM	Shared Decision Making

SEE	South-East Europe
SEERC	South East European Research Center
SPSS™	Statistical package for social sciences
STIKK	Kosovo Association of Information and Communication Technology*
TAM	Technology acceptance model
TAM2	Technology acceptance model 2
TPB	Theory of planned behaviour
TRA	Theory of reasoned action
TTF	Task-technology Fit
UCCK	University Clinical Centre of Kosovo*
UMTS	The Universal Mobile Telecommunications System
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
UTAUT	Unified theory of acceptance and use of technology
WHO	World Health Organization

List of publications

Publications in journals:

Basholli, A., Lagkas, T., Bath, P.A. & Eleftherakis, G. (2021). Sensor-based platforms for remote management of chronic diseases in developing regions: A qualitative approach examining the perspectives of healthcare professionals. *Health Informatics Journal, 27*(1). Doi: 10.1177/1460458220979350

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International Conference on Health Informatics HEALTHINF, Eseo, Angers, Loire Valley, France, pp. 511-516, 3-6 March 2014. ISBN: 978-989-758-010-9.

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Chapter 1 Introduction

1.1 Introduction to this thesis

This thesis is an investigation of healthcare professionals' attitudes, and acceptance before and after proposing a sensor-based architecture that enables remote and continuous monitoring of chronically ill patients' vital signs, in a developing country, Kosovo, which was the setting for this study. The proposed sensor-based platform in this thesis may address the needs of healthcare professionals for remote and continuous monitoring, as it considered their suggestions during the first interview study (chapter 5). Furthermore, healthcare professionals had the chance to use and perform some tasks with the proposed and implemented sensor-based application, as part of the evaluation study in this thesis (chapter 7). These empirical studies also addressed this thesis research questions that emerged after the literature review (chapter 2) as presented in subsection 2.8.3. In this way, it is hoped that this research will contribute to the sensor-based network (SBN) area and user adoption, to address their needs in improving the provision of healthcare services and enhancing patient care.

This chapter is organized to present an introduction to this thesis by first presenting the background of the research topic in section 1.2. The introductory information of the environment where this research was conducted are presented in section 1.3. The rationale and motivation to conduct this research are elaborated in section 1.4. Section 1.5 states the aims and objectives of this thesis. Section 1.6 presents the structure of the thesis and section 1.7 concludes with suggestions for the next research steps.

1.2 Background

In the literature, there is no universal agreement on the definition of the developing countries and classification on which countries fit a category. According to O'Sullivan and Sheffrin (2003), developing countries are defined as regions with a less developed industrial base relative to other countries and a low Human Development Index[1] (HDI). Another term that refers only to the economy of the country and is used interchangeably is also the low-and-middle-income country. This is closely related to the World Bank classification based on Gross National Income[2] (GNI) per capita. Hence, the World Bank (2021) categorizes world's economies into high-income (GNI per capita: $12,696 or more), upper-middle-income (GNI per capita: $4,096 and $12,695), lower-middle-income (GNI per capita: $1,046 and $4,095), and low income (GNI per capita: $1,045 or less) countries. This thesis will use the terms "developing country" and "low-and-middle-income country" interchangeably considering the same context.

[1] The HDI aims to present the development of a country in the context of its people and capabilities, and not the economic growth rate. Hence, it defines a statistical index of years of school, life expectancy, and gross national incomes per capita.

[2] The GNI presents the gross amount of money claimed as earned by people and businesses of a nation.

Developing countries are facing a lot of health problems considering their limited resources, and the lack of healthcare professionals to provide health services for the increasing number of patients. Most of these countries have a limited budget allocated for patient expenses, hence individuals in such countries need to pay for most of the healthcare services on their own (Ministry of Health of Kosovo, 2016). The situation gets worse considering the statistical analysis presented by the World Health Organization [WHO] (2021a) where it is concluded that 85% of the “premature” (people of ages 30 and 69 years old) deaths from chronic diseases occurred in low-and-middle-income countries. The rapidly increasing rates of chronic illnesses are predicted to lead to greater poverty and affect countries’ economic stability by increasing household costs associated with healthcare (WHO, 2021b).

As a developing country (USAID, 2021), Kosovo is facing healthcare challenges and is struggling to provide quality health services to the increasing number of patients. The public healthcare services are provided at three levels: primary, secondary, and tertiary healthcare institutions; however, there is only one tertiary healthcare centre where all the highest specialized healthcare services are provided, the University Clinical Centre of Kosovo (UCCK) located in Prishtina, the capital city of Kosovo. The public health system has some limitations in the context of growing costs, limited resources and medication, lack of adequate medical support, and limited time to dedicate to patient care. As a report from the Ministry of Health of Kosovo (2016) showed, 86% of patients confirmed to have paid for medication, 59.5% for medical services, 33.4% for medical materials, 31.9% for consultations (including the private institutions), and 10% for food. These are considered to be additional expenses that exceed the monthly amount a working person gets in Kosovo (more details on this are provided in subsections 2.3.1 and 2.3.4). Therefore, the need for the management and treatment of people with chronic diseases in developing countries is accompanied by various problems that challenge the provision of high-quality, affordable, and accessible healthcare services (Lewis et al., 2012). In this context, the WHO (2021a) suggested reducing the risk factors such as, tobacco use, alcohol use, overweight/obesity, and applying low-cost solutions for the treatment and management of chronic illnesses, including digital technologies.

The concept of digital technology encapsulates new technological advancements that are used for communication and sharing of information between parties. These platforms are applicable also in the healthcare domain. For example, the application of digital technology for remote monitoring of patients’ living parameters, is considered an area under investigation by many academic researchers and people from the industry. Hence, SBNs are proposed as a new innovative and evolving technology that can be used to continuously monitor a patient’s health condition. The remote health monitoring technologies (also known as remote patient monitoring platforms, RPM) consist of tiny sensors embedded in single mobile devices, or even as wearables, and aim to monitor a patient’s health status by gathering values of vital signs and transferring them through a remote interface to a point accessible for the healthcare professionals.

Remote monitoring technologies in the healthcare domain present an emerging field towards distance-based, real-time and continuous monitoring of illnesses. Remote healthcare contains many categories (i.e., telehealth, telemedicine, mobile health, eHealth) that differ on their method and aim of providing health services and involvement of parties, i.e., HCP or patient, however, all correlate to the same goal of monitoring a patient outside the hospital by using digital technology. As described earlier, remote patient monitoring enables recording of vital signs that may lead to early detection of a possible illness, continuous and real-time recording of a patient’s condition, prevention and worsening of the health condition, reduced number of deaths, reduced hospital visits and hospitalization days, provision of accurate and specific readings on patient's condition by continuous monitoring, improved clinical therapies, and cost reduction (Malasinghe et al., 2017; Stanhope et. al., 2016). Therefore, the application of remote monitoring technologies within healthcare can help developing countries bridge the existing gap between patients' needs and health service delivery (WHO, 2011a).

Considering the need and the benefits of remote monitoring platforms, various studies have proposed the application of sensor-based platforms for monitoring vital signs related to chronic diseases (Alecu et al., 2017; Coulter et al. 2017; Humayun et al. 2017; Steel, 2017). Chronic diseases (also known as non-communicable diseases (NCDs)) are considered human health conditions that are persistent or long-lasting in their effects, such as cardiovascular diseases (e.g., heart attacks and stroke), chronic respiratory diseases (chronic obstructive pulmonary disease (COPD) and asthma), cancers, and diabetes (WHO, 2021b). These diseases are considered life-threatening as more than three-quarters of deaths in low- and- middle-income countries are due to chronic illnesses and, in the long-term, the healthcare costs will cause these countries to have serious losses in their Gross Domestic Product (GDP) and impoverish millions of people (WHO, 2017). Patients who are diagnosed with chronic conditions are high users of healthcare services because of the increased levels of hospitalization, the need for continuous monitoring and treatment, and longer hospital stays (Gaikwad & Warren, 2009). While the number of people diagnosed with chronic illnesses is increasing in both developed and developing countries (i.e., due to population ageing, lifestyle changes, etc.), developing countries, in particular, face specific challenges in meeting the needs of these people. For example, in developing countries access to medical services may be limited, there may be limited numbers of medical centres and resources available, financial support to meet local needs may be restricted by other pressures, and there may be a limited number of healthcare professionals to treat the increasing number of patients diagnosed with chronic illnesses (Uluc & Ferman, 2016).

The sensor-based networks, either as wearable units or single devices, are increasingly used for the primary assessment and continuous treatment (Hilty et al. 2021). Further to this, as reported by Spyglass (2019) various healthcare providers have integrated and plan to further expand the use and application of sensor-based platforms for continuous and remote monitoring of chronically ill patients. This is supported by the statistics on the number of connected devices which increased through the years, from 325 million in 2016 to 722 million in 2019, and is expected to reach one billion by 2022 (Piwek et al. 2016; Statista, 2021). Technological advances such as cloud computing, blockchain, innovations on sensors, and artificial intelligence (e.g., machine learning) enable the gathering, processing, storing, and sharing of a patient's information in a more integrated and secured way. Moreover, the combination of these platforms provides the possibility for real-time monitoring and feedback, which enable more effective clinical support and a detailed view of a patient's actual condition (Rohani et al., 2018).

The Covid-19 pandemic situation has motivated healthcare providers to further consider the application of remote monitoring platforms based on sensors as reported by VivaLNK (2021) and Hilty et al. (2021). This was evident also during the second empirical study conducted in this thesis (chapter 7). The interview study on the evaluation of the proposed sensor-based architecture in this thesis was conducted during the Covid-19 pandemic situation (December 2020 to February 2021) and it was evident that healthcare professionals, as participants in this study, discussed more in detail on the usage and application of the proposed sensor-based platform as a remote and continuous monitoring tool and how it could help in monitoring patients and avoiding hospital visits and hospitalizations, especially during the current period of time.

In this context, Majumder et al. (2017) concluded that the application of sensor-based platforms in healthcare can provide comprehensive information about a patient's vital signs in a non-intrusive and non-invasive way and at a relatively low cost. Money et al. (2015), suggested that the use of sensor-based platforms enables the patient to participate in making decisions about their care alongside the healthcare professionals. Davis, Freeman, Kaye, Vuckovic, and Buckley (2014) recommended that it is very important to engage end-users in the proposal, development, and implementation of a remote monitoring platform, as its adoption and usage depends a lot on the attitudes of end-users. Clifford (2016) highlighted that, for the successful implementation of digital platforms in developing regions, in addition to the infrastructure and resources being available, it is important to consider the incorporation of healthcare professionals as the frontline community that needs to be committed to working with them.

Given the increasing benefits, advances, and capabilities of sensor-based platforms, and the current lack of research on their acceptance, usage and implementation in developing countries in South-East Europe (SEE), especially in Kosovo, this thesis aims to identify clinical needs, medical personnel opinions, concerns, possible challenges, and attitudes towards remote and continuous monitoring of their chronically ill patients. Hence, the idea is to present the design, development, implementation and evaluation of a sensor-based architecture and the related empirical studies before and after proposing it. The following section provides some contextual information regarding the country in which the study was conducted.

1.3 Setting

This section provides details about the country in which the research of this thesis was conducted. Kosovo is considered an upper-middle-income country (World Bank, 2021) and the youngest one that declared its independence in 2008. Kosovo is located in the Balkan part of South-Eastern Europe and has a total surface of 10,908 km^2 (Kosovo Statistics Agency [ASK], 2021a). The total number of resident populations is 1,782,115, where 67% of them are between 15 and 64 years old (ASK, 2021a). Prishtina is the capital of Kosovo, and it is considered the largest city and the business, cultural, administrative, organizational, and educational centre of the country. Kosovo has a further 37 municipalities.

The GDP per capita of Kosovo was recorded at $4462.40 in 2019 (Trading economics, 2021). Nevertheless, Kosovo remains one of the poorest countries in Europe with high unemployment rates and the majority of families living with less than €500 per month (World population review, 2021). A detailed cost analysis is presented in chapter 2, subsection 2.3.4.

The healthcare system of Kosovo still has marks of the war conflict of the year 1999, from which 90% of public clinics and hospitals were damaged, and nearly 100% of private healthcare institutions belonging to Albanians were destroyed (Brizendine, 2020; Privacy Shield Framework, 2021). Hence, challenges that the healthcare centres are facing have to do with the lack of medical equipment, limited resources (e.g., hospital beds, spaces, medical facilities, the basic medication that healthcare centres should have) to treat the increasing number of patients, lack of guidelines and tools for standardized healthcare practices, no protocols that describe the roles of medical staff in primary and secondary medical centres for specific clinical conditions, and lack of healthcare professionals (WHO, 2019). Further to this, a recent report suggested that the healthcare sector is also facing corruption, i.e., the same healthcare professionals work both in private and public hospitals, and very often they refer patients from the public medical centre for further treatment at the private hospital (Brizendine, 2020). More details on the health organization and patients' health-related expenses are discussed in chapter 2, subsection 2.3.1.

Given these challenges, the healthcare sector of Kosovo is struggling to provide quality healthcare services, which was shown in various studies over time (Ministry of Health of Kosovo, 2016; Public Pulse, 2013). Nevertheless, the application of sensor-based platforms for remote and continuous monitoring could help further in providing better treatment, and easier management considering the limited resources as discussed above. Hence, the following section will provide more details on the rationale and motivation for undertaking this research.

1.4 Rationale and motivation for undertaking this research

The literature data and results of various studies presented in section 1.2, showed the benefits of using sensor-based platforms in the healthcare settings as preventive and monitoring tools towards the increasing number of chronically ill patients, especially in developing countries. As discussed earlier, Kosovo's health system is struggling to offer quality health services considering the challenges that it is facing. Hence, the rationale and motivation for undertaking this research, is to propose a sensor-based platform and investigate its adoption and application in Kosovo, a developing country: they are closely related with the following facts:

- Kosovo is a newly created developing country in SEE that has recently experienced war

  This means that the current healthcare infrastructure is under development and facing reconstruction issues. The health system still operates with old technological trends and equipment (Brizendine, 2020; Percival & Sondorp, 2010).

- Remote monitoring based on sensor-based platforms is not used for the treatment or management of chronic diseases

  The health providers still use traditional methods of providing health and medical care. Although various donations were provided to improve health quality, none of them was related to the application of sensor-based technology for the remote and continuous monitoring of chronic conditions (WHO, 2019).

- The increasing number of ageing populations

  The number of births has been decreasing lately in Kosovo and, according to the Kosovo Statistics Agency (2013a), this number will decrease further from 2.0 children per woman as it was in 2011, to 1.7 children per woman in the year 2031, and 1.5 in the year 2061. Hence, this will cause an increase in the ageing population that will need monitoring. In this way, considering the year 2011, the percentage of Kosovo population over 65 years old was 6.9% of the total population. This number is expected to become 40.6% by the year 2061 (ASK, 2013b).

- The increasing number of chronically ill patients

  During the war conflict (1998-1999), chronic diseases were the second leading factor of death in Kosovo (Spiegel & Salama, 2000). These numbers continued to increase and from the total number of deaths in the years 2010-2011, 59.27% were caused by chronic conditions (ASK, 2013a). Similar increased numbers of chronically ill patients were reported for the period of years 2012-2013 (ASK, 2013a). Jerliu, Ramadani, Mone, and Brand (2013), in their investigation with the elderly Kosovar population, found that 83% of the total number of participants (N=1890) reported at least one chronic condition, where cardiovascular diseases were dominated by 63% of the 83%.

- Limited access to medical services

  Almost 90% of the chronically ill interviewees in the study conducted by Jerliu, Toçi, Burazeri, Ramadani, and Brand (2013), reported that they had difficulties accessing medical services. They also indicated that one of the reasons for this was their economic situation, where 87.7% declared that they could not afford the cost of health services. Further to this, the Ministry of Health of Kosovo (2016) reported that 30% of the population lives in poverty with €1,72 per day, which is supposed that almost one-third of Kosovo's population do not have access to medical services, or have limited access, due to the economic situation.

- Limited number of medical staff

  According to Percival and Sondorp (2010), there are around 13 doctors for every 10,000 inhabitants, whereas in other developed European countries there are 35 doctors per 10,000 inhabitants. Another recent report from the Health Policy Institute (2013) showed that the total number of medical staff is around 2003 doctors and 1059 nurses. Compared to the total population in Kosovo, this means that there are around 1.15 doctors and 3.84 nurses per 1,000 inhabitants. Brizendine (2020) reported that family medicine centres of Kosovo, where secondary healthcare services are provided, have at least 2 nurses and 1 doctor per 2,000 people in the area of that medical centre. Research conducted by WHO (2019) in Kosovo's medical centres, reported the workload of doctors in family medicine centres, where they consult around 100 patients during a shift of up to 17 hours.

- Lack of public health insurance

  The Assembly of Kosovo voted for the public health insurance law in 2014 (Official newsletter of the Republic of Kosovo, 2013) in an effort to provide a legal foundation of the Health Insurance Fund. Nevertheless, in 2021, Kosovo still lacks the provision and access to public health insurance. The lack of corresponding infrastructure and challenges related to its implementation are closely related to the high unemployment rates (Brizendine, 2020).

- Internet Penetration

  According to the Digital Economic Society Index (DESI), internet penetration and its frequency of use, activities online, and transactions performed, present some of the key elements for the development of the digital society (Regional Cooperation Council, 2021). In this regard, the internet penetration in Kosovo is reported to be comparable with other European developed countries (ASK, 2021d). This is due to the improved network infrastructure and technologies applied in the telecommunication industry in Kosovo. Another recent report from Kosovo Agency of Statistics (ASK, 2021d) showed that 96.1% of Kosovo households are connected to the Internet. This presents a distinct advantage for setting up and implementing a sensor-based architecture. More details on this are provided in subsections 2.3.1.4 and 2.3.1.5.

Consequently, the proposal of a sensor-based platform based on a country's need as discussed above, and taking into account users' attitudes, presents a promising and initial step towards helping a developing country, in this case, Kosovo, for better treating and managing the increasing number of patients considering its actual capacities. Nevertheless, the proposed sensor-based architecture and related findings may, at least to an extent, be applied to other developing countries with similar characteristics to Kosovo, which further enriches the contribution of this thesis.

1.5 Research aims and objectives

The purpose of this thesis was twofold. The overall aim was to understand the needs and acceptance of sensor-based platforms in a developing country, using Kosovo as a setting and, based on that, to propose a remote and continuous monitoring application for chronically ill patients. The design and implementation of the proposed sensor-based architecture were based on healthcare professionals' suggestions, current practices, and their needs for a patient's vital signs to provide remote feedback and continuous monitoring. The second aim was to provide recommendations and guidance for system designers from the HCPs' point of view, regarding the functionalities that they perceived as being useful and needed to monitor patients with a chronic illness at a distance.

Consequently, this thesis defined the following objectives:

- To analyse the current application and use of remote monitoring technologies, and following this, elaborate the benefits and impact of having real-time and distance-based monitoring of vital signs using sensor-based platforms;
- To review the existing user acceptance models and identify prominent models that may be used to understand healthcare professionals' acceptance and adoption of sensor-based platforms for remote and continuous monitoring of chronically ill patients;
- To identify the current needs, existing practices that healthcare professionals have, and the key vital signs they need, to monitor chronically ill patients at a distance;
- To propose a feasible and cost-effective sensor-based platform that enables remote and continuous monitoring of chronically ill patients;
- To empirically evaluate the proposed sensor-based platform based on feedback from healthcare professionals;
- To provide model guidance for system designers from the healthcare professionals' point of view.

A thorough literature review (chapter 2) and, following that, the updated research search (section 2.7) and critical discussion (section 8.3) showed no previous studies on healthcare professionals' acceptance of sensor-based platforms and proposal of such an application for remote and continuous monitoring have been conducted previously in Kosovo, nor any developing country in SEE. This is further supported by Tables 2.4 and 2.5, which list the similar sensor-based platforms that enable monitoring of chronically ill parameters. Hence, all of them were proposed, or developed, or designated in a developed country and, as far as can be seen from the literature, none have been proposed in Kosovo until now. As such, the results of this study may therefore contribute to enriching this research area and provide guidance and new knowledge that can be applied to other developing countries with similar characteristics to Kosovo. In this context, after reviewing the existing research studies and the literature gap, this thesis formulated a set of research questions as presented in subsection 2.8.3, that will address the aims and objectives presented here.

1.6 Contribution of this thesis

The research conducted in this thesis contributes to new knowledge in sensor-based research, with empirical findings from two interview studies with healthcare professionals, and the proposal and implementation of a sensor-based prototype which was designed based on the findings of the interview study. The study hence provides a unique and feasible remote and continuous monitoring platform.

Consequently, considering that the healthcare centres in Kosovo did not apply any real-time and distance-based form of monitoring and communication platform with their remote patients, the investigation of the attitudes of HCPs and their likely adoption of a sensor-based platform before proposing it, was seen as appropriate. Hence, various technology acceptance concepts were incorporated in the design of both interview studies.

This study incorporated practices and knowledge from different disciplines such as health informatics (sensor-based platforms, eHealth, remote monitoring), social sciences (technology acceptance), healthcare (chronic diseases, vital signs), and computer science (implementation of the sensor-based prototype). As such, this study is highly interdisciplinary.

1.7 Structure of the thesis

This thesis is structured to provide a detailed overview of the work conducted to understand healthcare professionals' acceptance and adoption of sensor-based platforms and, based on that, to design and propose a feasible sensor-based system that enables remote and continuous monitoring of chronically ill patients.

A detailed literature search containing information on the setting of this thesis, the sensor-based platforms and their application in healthcare settings, and a critical review of existing studies, is provided in chapter 2. This chapter presents the key findings, emerging issues and the identified gaps that this thesis aims to fill by addressing and answering the corresponding research questions.

Chapter 3 elaborates the research methodology and the methods that this thesis used to fulfil the predefined aims and objectives. The research ethics, sampling techniques and triangulation process are also described in this chapter.

Chapter 4 presents a detailed design of both of the interview studies conducted in this thesis. Furthermore, it provides a summary of the formulation of the interview guide, data collection, setting, and data analyses process that both empirical studies followed.

The details of the first interview study conducted with healthcare professionals to understand their attitudes and adoption of sensor-based platforms are elaborated in chapter 5. This chapter contains the study findings, a discussion based on technology acceptance concepts, and emerging needs to provide remote and continuous monitoring.

Chapter 6 considers healthcare professionals' opinions and needs to design and propose a sensor-based architecture. Further to this, the implementation of the proposed sensor-based prototype is described in the technical context in this chapter.

The details of the second interview study conducted with healthcare professionals to evaluate the proposed sensor-based prototype are presented in chapter 7. Similarly, as in chapter 5, here are also included the study findings, a discussion based on technology acceptance concepts, and the evaluation results.

Chapter 8 critically discusses the overall thesis findings that emerged from both interview studies. Furthermore, this chapter presents the findings of both empirical studies alongside each other and relates them using the process of triangulation.

Chapter 9 summarizes the overall thesis findings by presenting the aims and objectives outcomes, contribution to new knowledge, and benefits for end-users and healthcare institutions. This chapter provides suggestions for future work and implications for practice and policy.

1.8 Conclusions

This chapter presented a preliminary and summarized idea of the whole research study conducted in this thesis. Considering the background information and the needs of developing countries, more specifically, Kosovo, as a setting for this thesis, this chapter presented the rationale and motivation for undertaking this research (section 1.4). Several arguments motivated the work for the proposal of a sensor-based platform for remote and continuous monitoring of chronically ill patients in Kosovo. Furthermore, there was a need to understand healthcare professionals' acceptance and adoption considering that no previous work was done in this regard. Hence, following a thorough literature search, this thesis will identify existing platforms, their application for developing countries, and emerging issues and possible gaps that need addressing. The literature review is presented in the following chapter 2.

Chapter 2 Literature Review

2.1 Introduction

Following the introduction of the aims and objectives of this research study, the rationale, and an overview of the setting, as presented in chapter 1, there is a need for an in-depth literature review on the area of sensor-based platforms for the healthcare settings. Hence, the focus is to investigate previous studies, research, and related work that has been undertaken on the proposal, development, and implementation of feasible and cost-effective solutions of sensor platforms, for remotely monitoring chronically ill patients. This knowledge will then be applied to designing a study in a developing country, Kosovo, which will be used as a case study here.

The application of digital technology in healthcare presents an evolving research area. There are designed and implemented various architectures and systems that aim to improve healthcare services in different areas of application, and designation of usage, which also differ on the technologies involved. This study aims at investigating the application of sensor-based networks that are designed for continuous and remote monitoring of chronic diseases in developing countries. Therefore, this literature review presents a starting point for researching similar applications, previous work, and identifying the research gap.

This chapter provides a review of the literature and begins with the search strategy in section 2.2. Section 2.3 presents the need for remote and continuous monitoring in healthcare by introducing Kosovo as a developing country and a setting for this thesis. Further details on demographics, health organization, healthcare expenses, network infrastructure, and internet penetration are elaborated to support the identified need for sensor-based platforms in this developing country, as discussed in chapter 1, and to present the existing infrastructure for implementing such applications. The idea of SBNs is briefly presented in subsection 2.3.2, and the healthcare setting where to apply them is discussed in subsection 2.3.3. A cost analysis based on literature data compared existing patient's expenses in Kosovo, and the cost of industrial sensor-based platforms, is presented in subsection 2.3.4. Existing sensor-based platforms proposed for the healthcare settings (subsection 2.4.1) and specifically for monitoring chronic conditions (subsection 2.4.2) are critically analysed in section 2.4. Section 2.5 presents a review of technology acceptance theories, while section 2.6 presents similar approaches that used such models to understand users' acceptance of sensor-based platforms. An update of the literature is presented in section 2.7 to reassess and compare the literature before the commencement of the empirical research, and after finishing the interview studies (chapter 5 and chapter 7). Section 2.8 synthesizes the key findings of this literature review, emerging issues, and the research questions to address the identified gaps. Finally, this chapter's conclusions are briefly presented in section 2.9.

2.2 Search strategy

A comprehensive search of the relevant literature was performed at the beginning of this thesis and was updated throughout the research study. The literature review undertaken for this research study, aimed to help in developing a clear understanding of the existing sensor-based platforms for remote and continuous monitoring of chronically ill patients in developing countries, the issues, and the factors affecting successful proposal and implementation of eHealth solutions through technology acceptance constructs. Hence, the literature review in this thesis followed a more traditional social sciences approach that aimed to analyse and summarise a body of comprehensive research, which helped to identify research gaps, draft emerging issues and identified the need for the work of this thesis. Through this approach, the research presented in this chapter consists of the identification of the problem domain (section 2.3), critical discussions of the research that has been undertaken (sections 2.4 and 2.6), identification of areas that need further elaboration and investigation (subsection 2.8.2), and developing the research questions to fulfil the objectives of this study (subsection 2.8.3).

As such, the literature search included peer-reviewed articles published in scientific journals, conference proceedings, online articles published by companies that offer sensor-based solutions for health monitoring, and/or edited books. The search was limited to articles published in English and Albanian.

2.2.1 Range of terms

This thesis utilized a taxonomy of literature review following Cooper's (2010) recommendations. Hence, the literature search was broken down into different attributes expressed through a range of terms as elaborated in the following. According to Cooper (2010), the 'focus' characteristic is related to a study's analysis, findings, and methods used (chapter 2 and chapter 3); the 'goal' characteristic which is related to the identification of central issues, i.e., critical review of existing studies, research gaps or key contributions (section 2.8); the 'perspective' factor which in this study is applied to focusing in the theories or frameworks which are utilised here (section 2.5); the 'coverage' characteristic which is related to filtering information which is considered relevant to a research topic, i.e., for this study the application of SBN for chronic diseases.

According to the approach above that was followed, the key terms used during the literature search differed from the phase of the research. During the initial phases of research, the keywords and search terms included: sensor networks, e-health, health informatics, medical sensors, sensor networks in healthcare, sensor networks for patient monitoring, sensor network for continuous monitoring, eHealth solutions for chronic diseases, eHealth in developing countries, and sensor platforms for chronic diseases. The second phase of the review involved the research methodology, technology acceptance models, and proposal and implementation of sensor-based platforms. As such, it included terms like eHealth qualitative study, research methodology applied in healthcare, technology acceptance in qualitative research, and technology acceptance models (i.e., TAM, TAM2, UTAUT).

2.2.2 Databases and time frame of the literature review

For the literature search, the following databases were mainly used: Web of Science, Pubmed, Science Direct, IEEE, Scopus, and Google Scholar. The initial literature review was conducted in 2013 and 2014. However, this literature search was updated continuously for the empirical studies conducted throughout this research study during the years 2016, 2017, and 2021. As such, the literature search included articles from a wide range of dates, starting from year 1993 when various academic and industrial initiatives first started towards applying sensor-based platforms into various domains, including healthcare (Silicon labs, 2021).

The literature review started by elaborating on the application of sensor-based platforms in healthcare. Considering low-and-middle-income countries, this study aimed to understand the health sector where to apply the SBNs and help in this way the patient, HCPs, and medical institutions. After a thorough analysis and evaluation of various factors (the increasing ageing population, an increasing number of people diagnosed with chronic diseases, and the deaths caused by them, as discussed in sections 1.2 and 1.4), this study decided to investigate the sensor applications for remote and continuous monitoring of chronically ill patients in Kosovo and conduct the empirical studies. As various researches for the application of sensor networks for improving health provision and enhancing healthcare in general, were already proposed, this study concentrated on advantages and disadvantages of the already existing applications and critically analysed their suitability for developing countries and with the focus on remote and continuous monitoring of chronic diseases. The thematic structure of the literature review is presented in Figure 2.1.

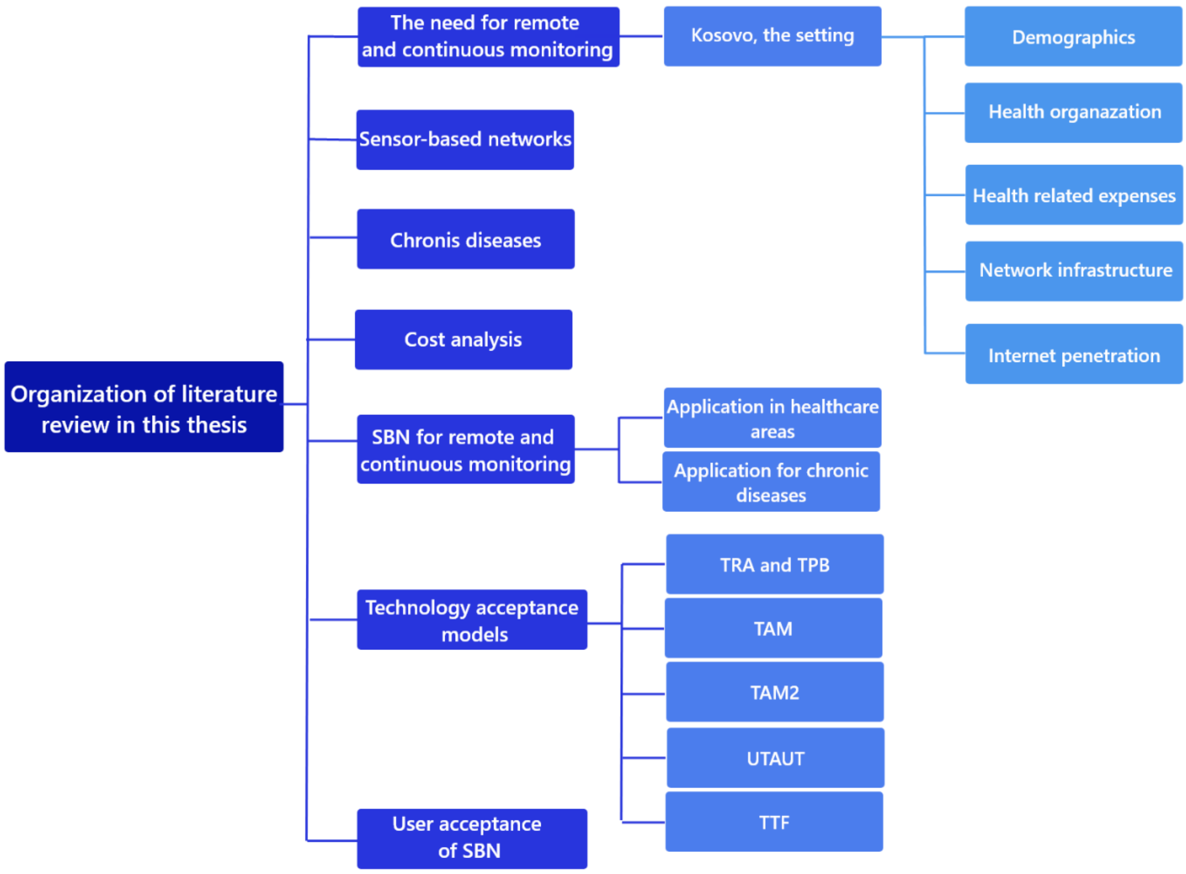


Figure 2.1 Organization of literature review themes in this thesis

As seen in Figure 2.1, this chapter is organized to present detailed information on the relevant themes that were identified and which emerged, regarding remote and continuous monitoring of chronic diseases. Hence, the remaining section and subsections of this chapter, are organized according to the order in which are shown in Figure 2.1.

2.3 The need for remote and continuous monitoring in healthcare

This section provides a detailed analysis and presents information on the demographics, economy, and network infrastructure of Kosovo, where the empirical studies (both qualitative studies presented in chapter 5 and chapter 7) were undertaken. The idea of sensor-based networks and their application in healthcare is presented in detail in subsection 2.3.2. As presented earlier, this research study aimed to use sensor-based platforms for helping chronically ill patients. Hence, the details related to chronic conditions, vital signs that need consideration, and measuring methods, are presented in subsection 2.3.3. To provide an argument and a crucial reason why developing countries may need a feasible and cost-effective solution to help them cope with the increasing number of chronically ill patients, subsection 2.3.4 presents the cost analysis related to health expenses and average financial incomes of patients in Kosovo, the setting for this research.

2.3.1 Kosovo - the setting for this research

This section provides information on Kosovo, the country in which the study was carried out. Hence, the health organization of Kosovo is elaborated to provide an example of a system of a developing country that needs remote and continuous platforms for monitoring chronically ill patients. The remaining sections are organized to present detailed information on the health organization, the healthcare expenses in medical centres, the existing network infrastructure, and Internet penetration and usage.

2.3.1.1 Demographics

More than 67% of the population of Kosovo is between 15 and 64 years old, as shown in Figure 2.2. Kosovo is categorized as having a relatively young population, as 24% of the population is younger than 15 years old, and half of the total population is less than 28.2 years old (ASK, 2019a).

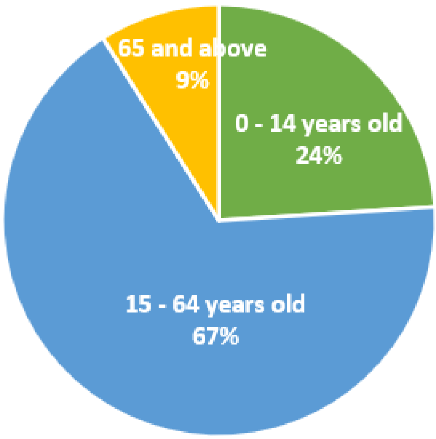
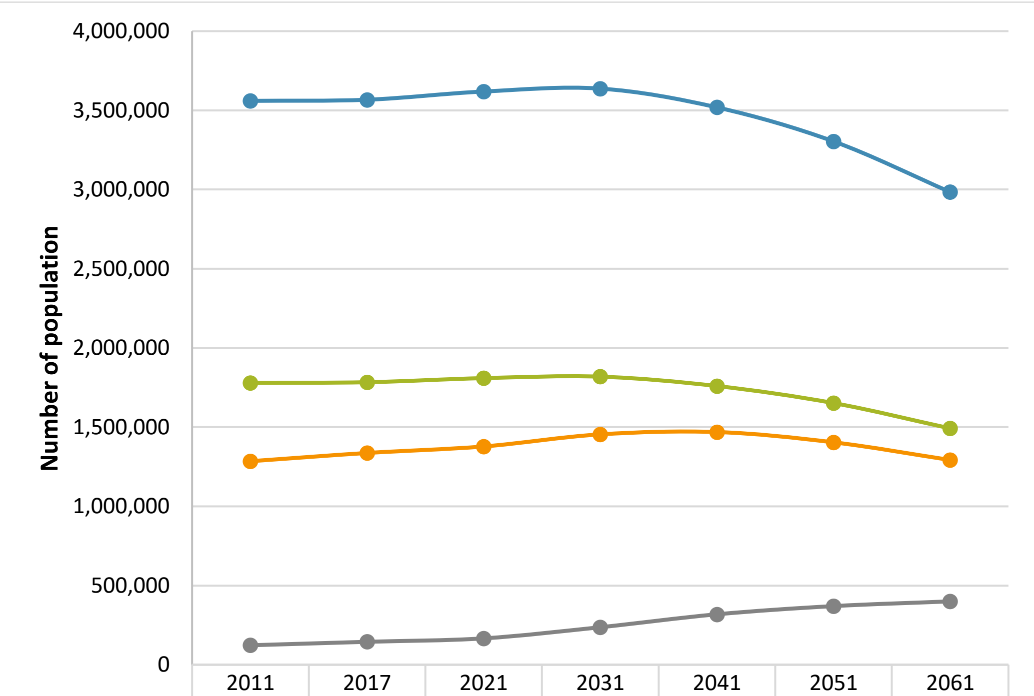


Figure 2.2 Kosovo population (adapted from ASK, 2019a)

Nevertheless, the number of populations is expected to decrease during the coming years. This was estimated in a study presented by the Kosovo Statistics Agency (2018), as Figure 2.3 shows. Even though there are some estimated numbers of the population in the coming years based on the current situation and the corresponding life expectancy parameters. The projected number of the population presented in Figure 2.3 is based also on the decreases in birth which is a trend reported lately (ASK, 2019a). Therefore, considering various factors, such as female education, their employability, economic situation; the number of births is expected to decrease further (ASK, 2018).



	2011	2017	2021	2031	2041	2051	2061
Total	1,780,021	1,783,531	1,809,458	1,818,674	1,759,492	1,652,090	1,492,192
0 - 14	495,101	446,633	431,526	364,294	290,436	247,855	199,518
15 - 64	1,162,044	1,192,181	1,211,592	1,217,592	1,150,779	1,034,147	892,803
65+	122,876	144,718	166,341	236,787	318,277	370,088	399,871

Figure 2.3 Kosovo population based on age, starting from 2011 and an estimation up to the year 2061 (adapted from ASK, 2018)

Following the decreased number of younger people, Kosovo is expected to have an increased number of elderly people for the following years as estimated by the Kosovo Statistics Agency (2013b) and presented in Figure 2.3. This has an impact also in the healthcare system of Kosovo, as there may be a greater need for healthcare services to serve the needs of the increasing number of elderly people. Therefore, the following subsections will provide details on the health organization of Kosovo and costs related to healthcare services.

2.3.1.2 Health organization

The Ministry of Health of Kosovo presents the highest governmental body responsible for the health and wellbeing of citizens of Kosovo. Hence, the ministry has approved several regulations, laws, and created corresponding bodies and institutions which aim to provide appropriate information and services. Through the health strategies such as one presented in 2009 (Ministry of Health of Kosovo, 2009), the public healthcare services are provided into three levels, primary, secondary, and tertiary healthcare institutions.

The primary healthcare institutions are managed by municipalities across the country and aim to provide preventive measures through the implementation of the family medicine concept. Kosovo currently has 27 municipalities (ASK, 2019b) where the primary healthcare institutions (also known as family medical centres) are located, as shown in Figure 2.4.

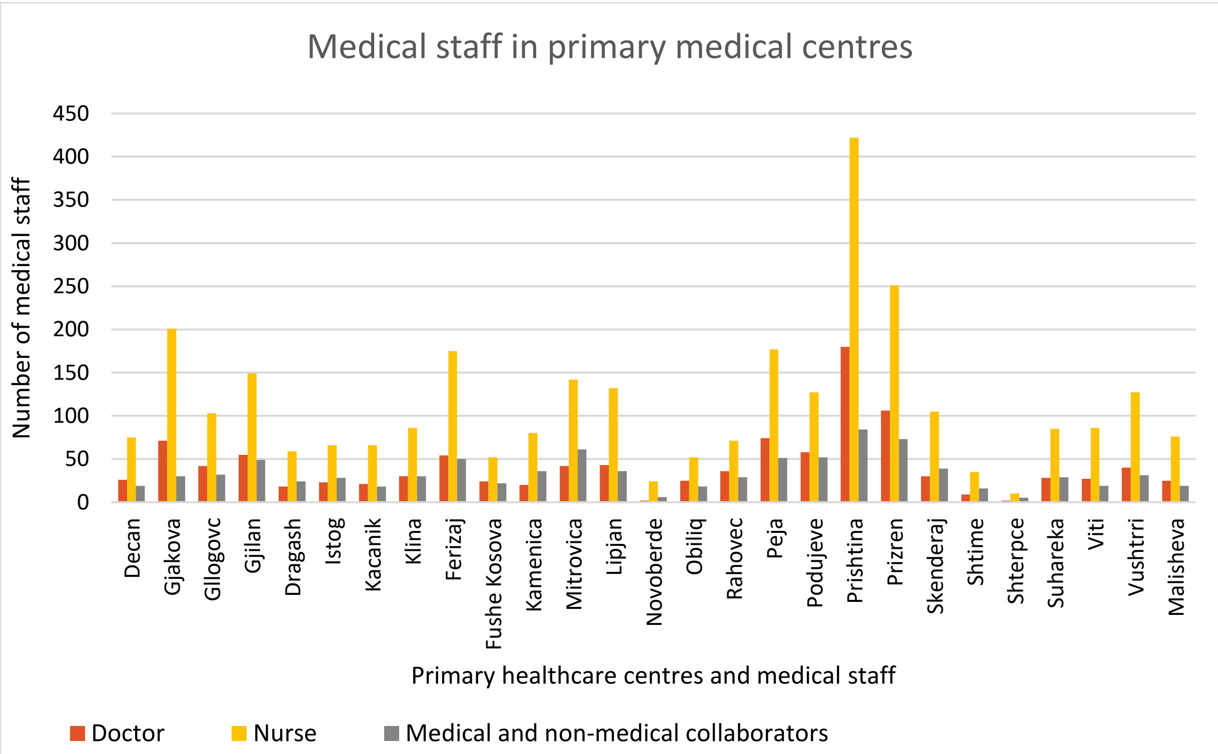


Figure 2.4 Medical staff in primary medical centres (adapted from ASK, 2019b)

Figure 2.4 shows an overview of the number of doctors, nurses, and medical and non-medical collaborators for every municipality that has a family medical centre and offers primary healthcare services. As seen in Figure 2.4, Prishtina[3], the capital city, has the highest number of doctors and nurses compared to other cities of Kosovo, proportionally with the number of residents there.

The secondary healthcare institutions are considered to be a higher level of health provision system, compared to the family medical centres presented previously. Hence, patients from the primary healthcare centres are advised to consult further for more specialized healthcare services to the secondary level of healthcare centres, known as regional hospitals. The regional hospitals are functional in larger municipalities of Kosovo, such as Mitrovica, Vushtrri, Peja, Gjilan, Prizren, and Gjakova. These institutions offer specialistic services including hospitalizations and oral health services. Prishtina does not have a regional hospital, but it uses the University Clinical Centre of Kosovo (UCCK) as a secondary and tertiary healthcare centre. Figure 2.5 shows the six regional hospitals and their corresponding medical staff.

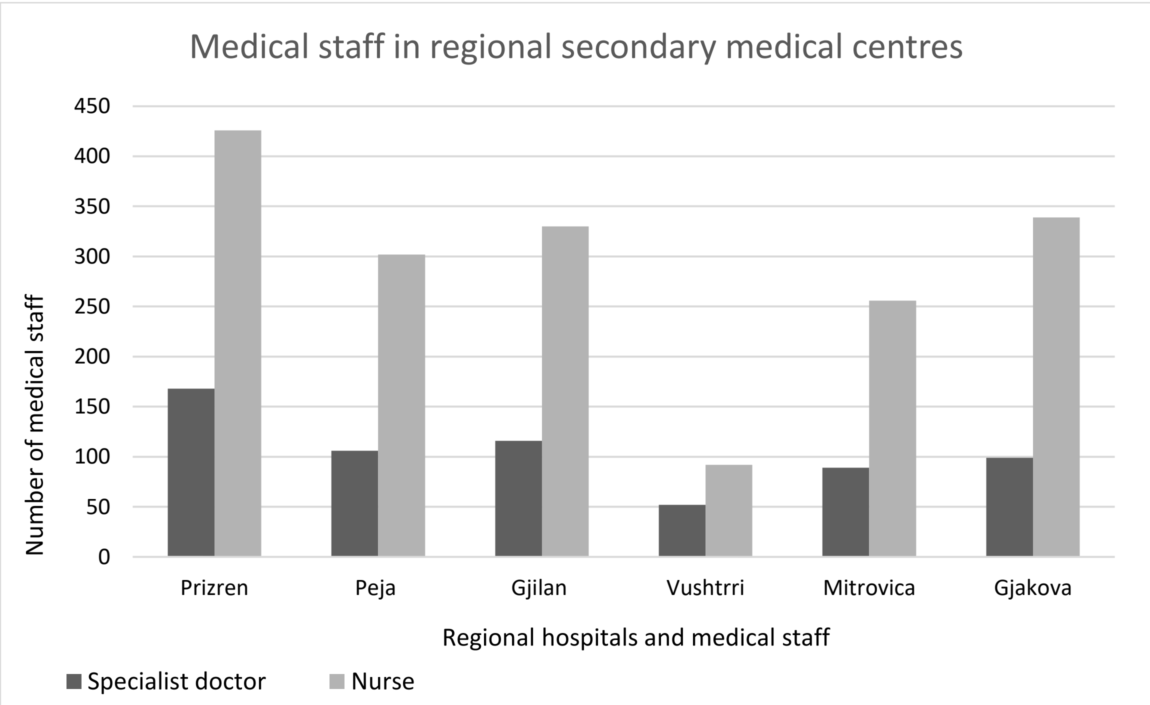


Figure 2.5 Medical staff in regional secondary medical centres (adapted from ASK, 2019b)

The tertiary medical institutions provide the highest specialized healthcare services, including lectures in the Faculty of Medicine and corresponding research in the medical field. The UCCK offers tertiary medical services through its 35 clinics (ASK, 2019b), as shown in Table 2.1. According to ASK (2019b) the total number of employees in the public health sector in 2019 was 13 518, where 3 555 of them were specialist doctors, 8 386 are nurses, and 1 577 are non-medical staff. Table 2.1 presents the number of specialist doctors and nurses for every clinic of the UCCK, including ones where chronically ill patients are treated (i.e., Cardiology, Pulmonology, Endocrinology).

Table 2.1 Medical staff in the clinics of UCCK (adapted from ASK, 2019b)

[3] The two qualitative studies conducted in this research study (Chapter 5 and Chapter 7), were performed in the American Hospital in Prishtina.

No	Clinic of UCCK	Number of specialist doctors	Number of nurses
1	Obstetric Gynaecological Clinic	56	245
2	Dermatology Clinic	19	25
3	Abdominal Surgery	58	52
4	Maxillofacial Surgery Clinic	13	20
5	Orthopaedic Clinic and Traumatology	34	80
6	Thoracic Surgery Clinic	13	29
7	Gastrological Clinic	11	22
8	Haematology Clinic	7	17
9	Neonatology Clinic	12	106
10	Infectious Diseases Clinic	24	71
11	Eye Clinic	29	52
12	Nephrology Surgery	17	65
13	Orth prosthetics Service	6	65
14	Pulmonology Clinic	16	37
15	Cardiology Clinic	30	85
16	Paediatrics Clinic	52	137
17	Endocrinology Clinic	13	16
18	Clinic of Anaesthesiology and Resuscitation	60	192
19	ENT Clinic	16	59
20	Neurology Clinic	24	65
21	Clinic of Medical Biochemistry	20	82
22	Nuclear Medicine Service	6	11
23	Emergency Clinical Service	27	91
24	Physiatry Clinic	16	63
25	Plastic Surgery Clinic	11	23
26	Neurosurgery Clinic	9	29
27	Urology Clinic	19	35
28	Oncology Clinic	20	45
29	Cardiac Surgery Clinic	22	56
30	Psychiatry Clinic	17	54
31	Radiology Clinic	28	61
32	Rheumatology Clinic	12	12
33	Paediatric Surgery Clinic	13	24
34	Vascular Surgery Clinic	9	30
35	Forensics	7	28

From the statistical data offered by the statistical agency of Kosovo in their latest report (ASK, 2019b), there were 3 953 887 patient visits to the medical centres across Kosovo. The majority of these medical visits were performed in secondary healthcare centres (around 880 367 visits). Nevertheless, the UCCK leads the number of hospitalization days (around 487 238) compared to other regional hospitals across the country. As reported in ASK (2019b) during the year 2019 with all these numbers and considering the overall capacity of medical centres in Kosovo, 71.2% of them were used.

The previous data were all related to public healthcare institutions; however, Kosovo has another 25 private licensed hospitals (ASK, 2019b) as shown in Table 2.2.

Table 2.2 Private licensed hospitals in 2019 and their type (adapted from ASK, 2019b)

	Number of hospitals	**Number of specialist doctors**	**Number of nurses**	**Number of beds**
General hospital	5	117	252	155
Special hospitals for ophthalmology	2	32	61	38
Special hospitals for cardiovascular diseases	2	38	65	33
Special hospitals for gynaecology, infertility, and endocrinology	5	91	181	82
Special hospitals for general rehabilitation	3	27	79	89
Special hospital for urology	2	11	31	38
Special orthopaedic hospitals	2	29	59	39
Special hospitals for surgery	4	84	111	102

As Table 2.2 shows, Kosovo has additional capacities through the private hospitals to manage its patients. Nevertheless, regarding medical doctors, most of them tend to work both in private and public hospitals. As seen from the participants of both interview studies conducted in this thesis (chapter 5 and 7), around 25% of the interviewees declared to work part-time in the private hospital and full-time in the public medical centres. As such, a report published by the Ministry of Health of Kosovo (2016) concluded that Kosovo has the lowest number of doctors and nurses compared to other EU or Balkan countries, as shown in Figure 2.6.

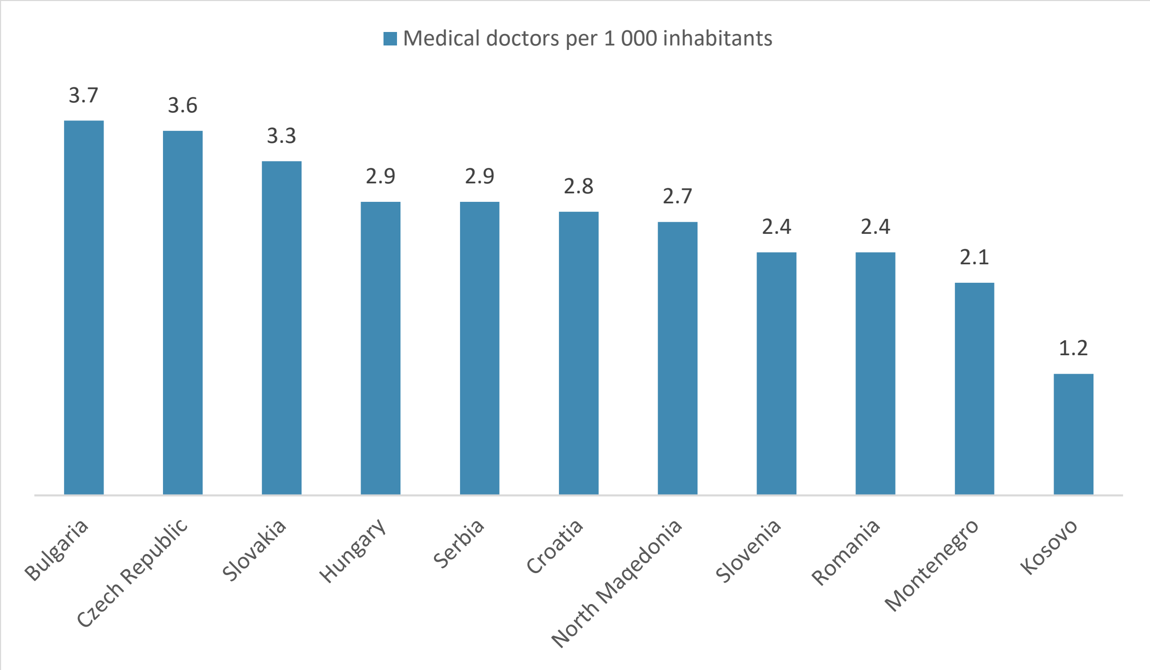


Figure 2.6 Number of medical doctors per 1 000 inhabitants (adapted from Ministry of Health of Kosovo, 2016)

Nevertheless, besides the low number of medical staff, 84% of the participants of the research conducted by the Ministry of Health of Kosovo (2016) evaluated the offered medical services as Good (4 of a Likert scale with 5 ratings) or Excellent (5 of a Likert scale with 5 ratings) for the public healthcare institutions and 94% for the private healthcare institutions. Only 19% of the participants had complaints about the way they were treated by the medical personnel, or on the amount of money they needed to pay for medical visits, medications, or other medical materials in the hospital. Similar findings were reported also in Public Pulse (2013), a study financed by the USAID and UNDP on patients' satisfaction with the medical services offered in Kosovo. Hence, the following subsection will provide more details on patient costs and related expenses to reach out to healthcare services.

2.3.1.3 Healthcare expenses in medical centres

As mentioned also in the previous section, there were several participants in the study performed by the Ministry of Health of Kosovo (2016) that reported additional costs especially for medication that should be provided by the public healthcare institutions themselves. Hence, 86% of patients confirmed that they had paid for medication, 59.5% for medical services, 33.4% for medical materials, 31.9% for consultations (including the private institutions), and 10% for food. These costs were the patient's related expenses to reach out to medical services. Considering that 29.7% of the population lives with €2.51 per day (Numebo, 2021), and 25.9% of them are unemployed (ASK, 2021b), it is supposed that 1/3 of the population do not have easy access to healthcare services, or may have limited access due to economic situation.

The financial problems that healthcare institutions in Kosovo are facing, may not only be because the government allocates few resources for direct patient-related expenses, but a part of these are used for fixed costs (buildings, maintenance, staff, energy, and similar) and only 32% of them can be used for costs related to patients, i.e., tests, medication, scans (Ministry of Health of Kosovo, 2016). This means that the other part of the allocated resources (68%) includes costs that will remain the same and do not depend on the number of patients.

The study conducted by Public Pulse (2013) showed that 95% of the interviewees have paid around three euro for general expenses and five euros for gifts for medical staff. Table 2.3 shows details on patients' expenses for receiving healthcare services.

Table 2.3 Related patient's costs for treating health problems in Kosovo (adapted from Public Pulse, 2013)

Costs paid	**Costs of public healthcare institutions**	**Costs of private healthcare institutions**	**Costs for medications**	**Costs for transportation**
€1 - €50	55%	35.7%	43.4%	59.7%
€51 - €100	14.4%	15.1%	17%	15.7%
€101 - €200	9.4%	12.8%	13.5%	10.6%
€201 - €400	8.2%	12.8%	8.4%	4.5%
€401 - €800	3.9%	7.7%	6%	4.8%
> €800	9.3%	16%	11.7%	4.6%

As Table 2.3 shows, the majority of patients have paid €1- €50 in the public healthcare institutions. The numbers of costs related to the private healthcare centres are slightly higher compared to public healthcare institutions, where a high percentage is noticed for the expenses more than €800. The majority of participants confirmed to have paid at least €1 – €50 for medication and transport to the nearest medical centre. The situation gets worse considering that 80% of these participants did not have health insurance (Public Pulse, 2013) and they needed to pay these costs themselves.

All these details present arguments supporting the need for a feasible and cost-effective solution that will offer better monitoring and easy-to-access healthcare services to patients through the application of sensor-based platforms. Hence, the following subsection will discuss the existing network infrastructure, the internet penetration, and its usage, to better understand the technical aspects of implementing sensor-based networks in a developing country such as Kosovo.

2.3.1.4 Network Infrastructure

The network infrastructure of Kosovo was mainly dominated by microwave links (Caka and Cakaj, 2002) up to the year 2002; however, networking and telecommunication links were further enhanced and digitalized with the establishment of fibre optic links and ADSL (Asymmetric digital subscriber lines) services. According to the data offered from the internet providers to the Regulatory Authority of Electronic and Postal Communications of Kosovo (ARKEP) presented in (ARKEP, 2019), there were more users connected using ADSL technology (around 35 717 users), compared to fibre optics (16 485 users) during the year 2017. Further to this, Kosovo's telecommunications sector offers similar quality of voice services to its users, compared to other regional countries and it is considered as the least expensive in the region (International trade administration, 2020).

According to ARKEP (2019), there are two authorized operators of the mobile telephony network, the Telecom of Kosovo/Vala and IPKO Telecommunications. In addition to these operators, the ARKEP has licensed another two mobile virtual network operators, the Dardafon.net (Zmobile) and Dukagjini Telecommunications (D3mobile). All these operators managed a total number of 2 032 182 users of mobile telephony, presenting an increase of 1.1% users as they were in 2016 (ARKEP, 2017). Further to this, the services offered, cover 100% of Kosovo's territory with GSM technology, and 70% with LTE. Figure 2.7 shows the territory coverage based on network operators and the technologies offered, according to the report presented in ARKEP (2019).

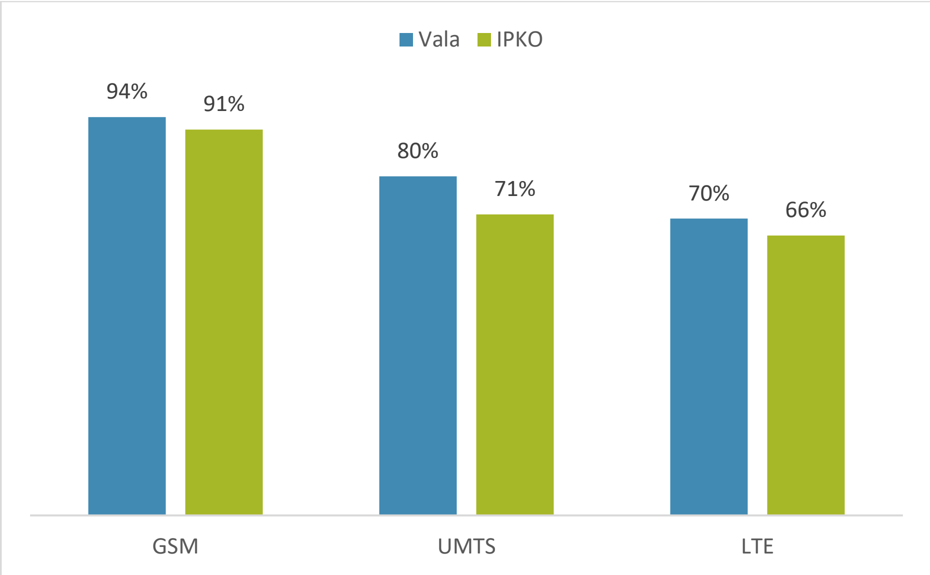


Figure 2.7 Coverage of network operators by the technologies offered (adapted from ARKEP, 2019)

As shown in Figure 2.7, the x-axis presents the technology offered, GSM, UMTS, or LTE, while the y-axis shows the coverage percentage based on Kosovo's territory offered by three licensed operators. Based on a report presented by the Kosovo Association of Information and Communication Technology (STIKK, 2013), IPKO dominates the Internet service provision (ISP) by having 35.49% of the Kosovo users, followed by other local ISP companies which are mostly supplied with services through major supplies. The local ISPs supply the rural areas mainly. Therefore, around 44.5% of the users of rural areas are covered by local ISP companies which do not have direct access to major companies like the rest of 55.5% of users (STIKK, 2013).

2.3.1.5 Internet penetration and usage

The digitalized and enhanced network infrastructure is closely related to internet penetration and its usage. Hence, the latest report of the Kosovo Agency of Statistics reported that 96.1% of Kosovo households are connected to the Internet (ASK, 2021d). Similar findings were reported also by the Kosovo Association of Information and Communication Technology (STIKK, 2019). In this context, referring to ASK (2021d), in 2017, approximately 88.8% of households in Kosovo had internet access, which was also considered a comparable number with other developed countries. Eurostat (2019) also reported that, in 2018, Kosovo had the highest rates of households' internet connections in the region with 93%.

The internet penetration rates have increased through the years. As presented in Figure 2.8 and reported by ASK (2020a), the percentage of families that had an internet connection in 2020 was 96.4%, and compared with years 2018 and 2019 there was an increase of 3.2% in the year 2020.

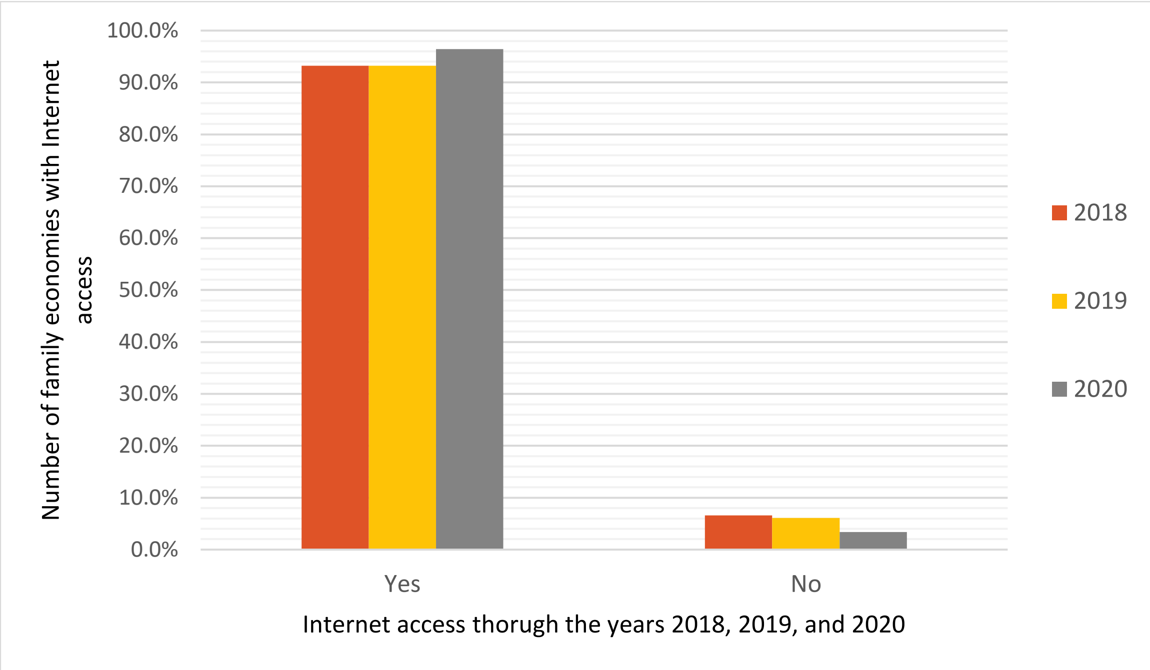


Figure 2.8 Users with Internet access at home or buildings through the years 2018-2020 shown in (%) (adapted from ASK, 2020a)

The study by ASK (2021d) on internet penetration and usage in Kosovo revealed that the majority of participants used mobile phones most of the time to connect to the Internet, as Figure 2.9 shows. Similar findings were reported also by ASK (2020a).

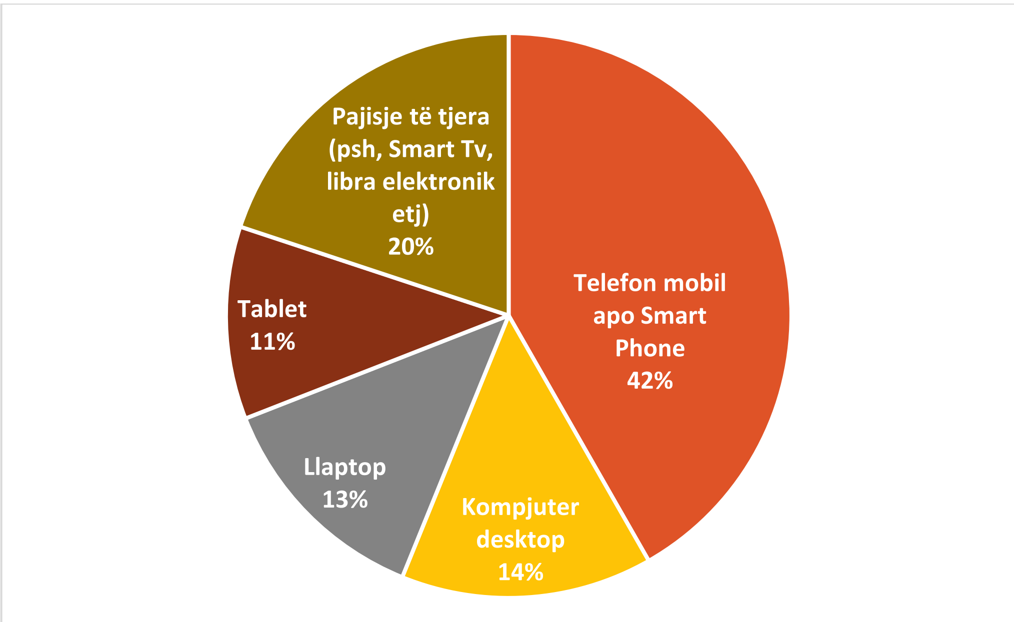


Figure 2.9 Internet usage in different electronic devices (adapted from ASK, 2021d)

Stable network infrastructure and high rates of internet connections and usages present advantages for a successful implementation of a sensor-based architecture in a developing country such as Kosovo. Furthermore, considering all the services offered by the ISPs and their coverage in urban and rural areas, which were comparable with other developed countries, provide a good starting point for the proposal of a feasible and effective solution for remote and continuous monitoring of chronically ill patients. Therefore, in the following subsection, further details are provided on the sensor-based networks and their application in the healthcare domain.

2.3.2 Sensor-based networks in healthcare

Basic medical care and continuous monitoring present an evident need that is in focus especially nowadays. The globalization of economies, the tendency of people to live in cities, and the evolving technological trends, also have a real impact on the health system. Moreover, taking into account that the world's ageing population is growing, consequently, the number of people living alone and who need continuous observation is increasing too. Therefore, the need for tools, applications or devices that can help ensure the wellbeing of the people who need continuous monitoring is needed (WHO, 2011b). In this context, sensor-based platforms can help to provide monitoring in distance and in real-time.

A sensor is a mechanism that can react to a physical stimulus, such as heat, pressure, sound, light, noise levels, motion, gravity acceleration, or the position of objects. This physical stimulus is converted into a measurable electrical signal that is transmitted further. As such, an SBN may consist of several sensor nodes that compose of field sensors, processors, and radio receivers, which are usually integrated into a micro board or integrated circuit. As such, sensor nodes can gather data, compute and process them using radio frequency links to the neighbours or gateway nodes depending on the network configuration and topology. Hence, the sensor nodes play the role of measurement collectors and traffic forwarders to the sink node or the base station (Voyiatzis & Serpanos, 2007). When forwarding gathered data, it is important to consider the transmission technology, for example, the usage of wireless communication links eliminates the need to integrate lead wires and fibre optics, in this way lowering the possibility of connector failures and network breakage, and high installation and maintenance costs (Townsend et al., 2005).

Sensor-based networks have some characteristics in common (Zheng & Jamalipour, 2009), that also distinguish them from other traditional wireless communication technologies like mobile communication systems, or ad-hoc networks, as follows:

- sensor nodes can be located at shorter distances, near to each other, to enable a better exchange of the gathered data and cover a specific research area,
- sensor nodes are easily deployed due to their possibility of the autonomous configuration,
- sensor networks present application-specific networks in the context that the network is designed for a specific application (i.e., healthcare).

SBN presents an important component of remote monitoring systems. They are used in electronic and medical systems to sense patients' physiological signs or convert vital signs into electrical signals which are transmitted to a point accessible by the medical personnel. As such, sensors are considered an important part of life-supporting systems and a preventive measure and long-term monitoring platform for disabled or ill patients (Angelov et al., 2019). Hence, a basic sensor-based architecture for healthcare designation may consist of three layers as shown in Figure 2.10.

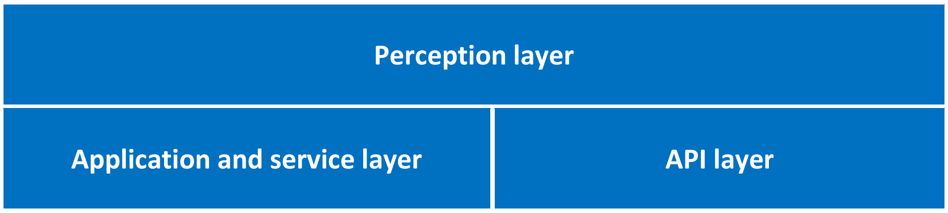


Figure 2.10 E-health sensor-based monitoring architecture (adapted from Angelov et al., 2019)

The perception layer may consist of different medical sensors which sense a patient's related vital signs, such as pulse, oxygen saturation, blood pressure, temperature, heart rate, and similar. The other two layers deal with patient information, that is why they are shown in the same level in Figure 2.10. The application programming interfaces (API) layer may process a patient's data, for example, store them in other platforms such as cloud databases or blockchain (Basholli & Cana, 2020), while the application and service layer may contain e-health applications (i.e., web-application or mobile application) that analyse patient's vital signs and process them in an understandable format to provide easy access to medical staff to read them and provide feedback to the patient. This is the general sensor-based architecture used also for this research study as presented in detail in chapter 6.

The following subsection provides more details on chronic diseases as a specific domain of healthcare where sensor-based platforms can help to provide remote and continuous monitoring and where this thesis is focused on.

2.3.3 Chronic diseases

Worldwide trends of the rapidly growing population of older adults, the increasing life expectancy, the high prevalence of risk factors, and disease dynamics foretell rises in the occurrence of chronic diseases and other chronic conditions (Li et al., 2011). Chronic diseases affect not only the elderly population, as Suhrcke, Nugent, and Rocco (2006) concluded around 44% of deaths appeared in the population of age below 60 years old. According to WHO (2011b), every year around 9 million people under 60 years old die due to chronic diseases whereas 90% of them occur in low- and middle-income countries.

In the literature, there are various definitions of chronic diseases. The WHO (2021b) defines chronic diseases to have a long duration and generally slow progression. Similarly, the Florida Department of Health (2021) describes chronic diseases as having a long course of illness that are generally not prevented by vaccination and have no cure by medication. Anderson (2010) presents chronic diseases as diseases that last a year or longer, that have an impact on the daily activities of a person, and illnesses that require ongoing monitoring and medical care. According to Aikins et al. (2014), patients in most cases do not know that they suffer from a chronic condition as they treat it as a normal condition.

To detect health problems on time and any possible deterioration, a patient's vital signs should be monitored continuously (Hutson & Millar, 2009). Hence, parameters that the patient and the HCPs need to consider for chronic diseases sometimes depend on a patient's age as there are physiological and pathological changes, stage of the disease, or a patient's care. However, in general, the five most common vital signs that need continuous monitoring in the case of a chronically ill patient are the respiratory rate, pulse rate, blood pressure, oxygen saturation, and body temperature (Chester & Rudolph, 2011). Below are provided details about the values and important considerations related to these parameters.

- Blood pressure

  While reading a patient's blood pressure, one should consider two values, the upper one, that is the systolic blood pressure, or the highest pressure that the heartbeats and pushes the blood around in the body; and the second one, is the diastolic blood pressure, or the lowest rate measured when the heart relaxes between beats. Therefore, the normal blood pressure rates are considered: 90- 120 mmHg systolic and 60-80 mmHg diastolic (Blood Pressure Association, 2015).

  Children or athletes usually have blood pressure between 90/60 mmHg. People who have blood pressure in the range 50/35 mmHg will be in a coma, and those having blood pressure in the range 180/110 mmHg have a high risk of cardiovascular disease, e.g., heart attack, stroke, or even death.

- Oxygen Saturation

  This value refers to the percentage of oxygen in the blood. In normal conditions, the majority of oxygen is transported by haemoglobin (red blood cells) and only a small part is dissolved in the blood. The normal level of oxygen in the blood is considered 95-100% (Schutz, 2001). The level of oxygen in blood below 80% may cause organ damages, such as brain damage or a heart attack.

- Body Temperature

  Body temperature is one of the vital parameters that is usually measured and monitored, and which may vary depending on the patient's gender, age, activity, fluid, and food consumption. A normal range of body temperature is considered 36.5 – 37.2 degrees Celsius (or 97.8 – 99 Fahrenheit) (Alecu et al., 2017; Kelly, 2006). The critical ranges of body temperature are hypothermia or low-temperature rate, where the temperature is around 34 degrees C; and high-temperature rate, one degree above the normal range.

- Pulse Rate

  Pulse rate presents the number of times the heart beats per minute. Moreover, the pulse rate also includes the heart rhythm and the strength of the pulse, as the heart should push blood through the arteries. The normal range of the pulse rate should be 60 to 100 beats per minute (Agrawal, 2008). However, this range may depend on a patient's activity, gender (females tend to have a faster pulse rate than males), injury, illness, or emotions.

- Respiratory Rate

  Respiratory rate is usually measured when the patient is at rest and consists of the number of breaths the patient takes in a minute by counting the number of chest rises (Agrawal, 2008). The normal range should be from 12 to 16 breaths taken in one minute. However, this range may be influenced by illness, fever- high body temperature, or similar medical conditions.

Vital signs are considered important indicators for monitoring and detecting possible medical problems at an early stage (Alecu et al., 2017). Nevertheless, as presented above for every vital sign, the acceptable values or the normal range may depend on multiple factors such as a patient's gender, age, weight, lifestyle, geographical location, medical background, physical health, and so on. Therefore, it is important to gather as much information as possible, to provide better diagnoses and therapies. The application of sensor-based platforms could help in this regard by enabling data collection, analyses, and presentation in a format that is readable and understandable for healthcare professionals. Besides these benefits, sensor-based platforms may be considered as a cost-effective solution for helping chronically ill patients in managing their conditions. Hence, details on a preliminary cost analysis are presented in the next subsection.

2.3.4 Cost analysis

Chronic diseases are causing the highest number of deaths worldwide and this number is increasing especially in developing countries (Guo et al., 2021, Horton, 2017, Suhrcke et al., 2006). According to WHO (2011b), nearly 80% of deaths in low- and middle-income countries are caused by chronic diseases and it is believed that during the next coming 15 years people will suffer disabilities or death more from non-communicable diseases such as heart disease, and diabetes, than from infectious and parasitic diseases. Moreover, WHO (2011b) reported that chronic conditions also present one of the threats for global economic growth and development, and low- and middle-income countries in the next 15 years may spend around 7 trillion dollars. This money may not be only for managing and curing chronic diseases, but also when many people in the workforce become sick and/or die, the national economies will lose their productive years and, in this way, the output products will be lower and the costs higher.

Developed countries also allocate high amounts of money to treat and manage chronic conditions. The United States of America spends an estimated 2 trillion dollars per year (WHO, 2011b). The cost of heart disease or stroke was around $394 billion in 2008 (Minaie et al., 2013). The study presented by Suhrcke et al. (2006) concluded that, for developed countries, the cost of chronic diseases varied from 1% to 3% of the GDP of the country, and for developing countries, the values varied between 1.8% to 5.9%. Similarly, Dugee et al. (2019) concluded that NCDs contributed to an 8% increase in the incidence of poverty. Considering the increases in the ageing population, where the older population is expected to outnumber the younger one, these values are likely to be even higher.

To help the healthcare centres deal with this situation, it is crucial to be able to provide high-quality and affordable solutions to people with chronic diseases. As the WHO (2011b) proposed, developing countries should develop a set of strategies to prevent, diagnose and treat chronic diseases like diabetes, heart diseases, and other related diseases, for a cost of just $1.20 per person per year. Further to this, for measuring and providing a cost-effective solution while dealing with chronic diseases, one should consider all actual costs, have reliable information related to health impacts in patients and discount the health costs for the future. Therefore, some cost-effective measures towards better treatment and management of chronic conditions may include non-clinical interventions, pharmacological approaches, using low-cost techniques, and continuous monitoring of vital parameters and those which may cause or have caused a chronic disease.

The application of digital technologies can improve the quality of health provision and reduce the corresponding expenses as already proved in different countries through various initiatives such as Health Information Technology Initiative (Health-IT) in the USA, U-Japan Initiative in Japan, i2010 Initiative in EU, and 11 Five Year (11-5) Plan in China (Wu, 2008). As such, these programs showed that continuous and at-home health services may provide a better life for chronic disease patients, and address their social and financial loads (Minaie et al., 2013). Suhrcke et al. (2006) considered the SBNs as a better and affordable solution in this direction. The application of sensor-based technology is considered to provide many advantages compared to traditional health offering tools, for example, ease of use, reduced risks of failure, reduced risk of infection, user comfortability, enhanced mobility, and lower cost of delivery. Moreover, their spread and usage are increasing continuously (WinterGreen Research, 2013). In the market, various sensor-based applications exist, which are proposed for monitoring patients' living parameters (some of these are mentioned also in section 2.4).

Zephyr presented a commercial product which is a wireless heart rate sensor application. This application can monitor heart rate, R-R interval, speed, and distance (Zephyr, 2021). The actual cost of this sensor application is around $74. Kito presented a smartphone cover that can monitor patients' heartbeat, blood oxygen, respiratory rate, body temperature, and take an ECG (Smythe, 2016). The patient needs to hold it with both hands, like taking a picture. The price of this product is around $199. According to Cherney (2021) for a patient without health insurance, a continuous glucose monitoring (CGM) device may cost at least $100 per month. Oyagüez et al. (2021), on the other hand, performed a cost analysis for the FreeStyle Libre 2 and concluded that this device can be considered as potentially enabling cost-savings to patients with type-2 diabetes in Spain. Hence, as authors reported using Libre 2, a patient can save up to €580 per year, considering that they need to pay around €2 700 per year for self-monitoring of blood glucose, and around €2 120 per year when using this sensor-based platform (FreeStyle Libre 2).

Considering Kosovo as a developing country, patients there need to pay around half of the total price of healthcare expenses at the moment of requesting them (Kosovo Democratic Institute, 2011). Based on the Uka (2013) report, the approximate price for healthcare services that a patient coming from a rural area needs to pay varies from €50 to €200. Considering the average wage of a working person to be around €466 per month, without taxes (ASK, 2021c), and the total sum of the overall basic utilities, rent, food and transportation expenses, it is concluded that these expenses exceed the total amount a person gets per month (Numbeo, 2021). This situation worsens even more if we consider that the vast majority of the population in Kosovo is unemployed and does not have public health insurance.

Taking into account the approximate price that the patient needs to pay for medical visits, healthcare services and possible medication which are not provided in the public healthcare centres in Kosovo as presented in subsection 2.3.1.3; and the prices of the above-mentioned industrial sensor applications (FreeStyle Libre 2, ZIO patch, Zephyr or Kito), it is evident that the price of the latter amounts to twice of the price of the visit. However, chronic diseases present conditions that need continuous monitoring, periodic medical visits, and therapies; therefore, the patient will have multiple costs which may exceed the price of a sensor device that is supposed to be bought once or for a longer period of time.

According to Aikins et al. (2014), patients in most cases do not know that they suffer from a chronic disease as they treat it as a normal condition. In some cases, even knowing it, they undertake very few preventive measures because of the poverty and high prices that they need to pay. Further to this, considering that the ageing population is increasing, they need to stay in their homes, or any place that they would feel comfortable and be able to receive monitoring and healthcare services from there and, in this way, to improve the quality of life and reduce travel and healthcare costs (Angelov et al., 2019). In addition to this, for developing countries, it is important to take into account the poorly trained healthcare professionals, lack of medical equipment, and expensive or unavailable medicines in the healthcare centres. Therefore, it would be helpful if there were technological solutions that would facilitate chronically ill patients' access to medical services, help healthcare professionals to provide better healthcare assistance, and contribute to the improvement of the healthcare system in these countries, such as Kosovo. Hence, the following section provides a detailed analysis and critical comparison of existing sensor-based platforms and how they differ from the approach followed through this thesis.

2.4 Remote and continuous monitoring through SBN in healthcare

This section provides details on the existing studies in the literature that have considered the application of sensor-based platforms in the healthcare domain. As there exist various researches that aim to improve healthcare services delivered to patients in need in different healthcare sectors, this section is divided to present the proposed sensor-based platforms applied in healthcare, in a general view in subsection 2.4.1, to continue further with the application of sensor-based networks for remote and continuous monitoring of chronic diseases, specifically, in subsection 2.4.2.

As such, this study had two criteria while reviewing SBN, the first one was related to sensor-based platforms that were applied for monitoring patients at home, i.e., smart home solutions, assisted living systems, consultation platforms, wearable platforms to detect falls and loss of consciousness (subsection 2.4.1), and then the study narrowed down to works that were designated to monitor chronically ill patients through sensor-based applications, at a distance (subsection 2.4.2).

2.4.1 Sensor-based platforms applied in healthcare

Sensor-based platforms have been proposed for application in various disciplines of healthcare. The Assisted Living[4] systems have been designated to help elderly people or those who live alone in their homes, to monitor their health condition (Holzinger et al., 2010; Iliev, 2009). Such systems consist of various types of medical and environmental sensors. In this context, the University of Rochester (2021) developed a medical consultation prototype, like a smart medical home, to provide virtual conversations between patients and medical personnel. The proposed prototype consisted of biosensors, infrared sensors, computers and video cameras, and it also offered the recording of the activity movements. Similarly, Aviles-Lopez et al. (2010) developed a lab to help people with physical, physiological and neurophysiological problems, such as Alzheimer's disease, dementia, diabetes, arthritis and cardiovascular diseases. The proposed platform had wearables in the form of a watch,

[4] The Ambient Assisted Living encompasses devices, systems, methods, and services offered to the user to facilitate his/her daily activities based on the needs.

bag, cup, or other embedded accessories in clothes. Hence, a wearable sensor-based system can be placed in different body areas and may consist of interconnected units such as sensors, analogue-to-digital converter (ADC), computing elements, antennae or radio frequency links, and power supply units. As concluded by Bharatula, Luowicz and Troster (2008), it is important to consider the wearability aspect of such platforms. Hence, the weight, size, form, heat generation, flexibility and power supply, which are some of the important features that the system designers should consider when aiming to propose sensor-based wearable platforms.

Holzinger et al. (2010) also proposed a wearable platform in the form of a wrist unit to monitor a patient’s vital signs and detect falls or loss of consciousness. Accelerometers and sensors were used in the prototype proposed by Healey et al. (2005) to record, analyse and transmit a patient’s echocardiogram data, as well as, motion, events, and activities. Similarly, Wang et al. (2006) proposed a prototype, as black-box equipment, which consisted of build-in sensors, actuators, and Bluetooth-enabled devices to provide remote monitoring and access to patient’s data for the healthcare professionals.

The Department of Computer Science of the University of Virginia constructed an experimental living space to test the proposed smart healthcare architecture (Virone et al., 2006). The introduced system architecture included motion sensors, body network sensors, indoor temperature and luminosity sensors, bed sensors and pulse-oximeter, and ECG sensors. Similarly, Bajorek and Nowak (2011) proposed a home monitoring healthcare system that was intended to overcome security and data protection issues. This system architecture was very similar to the previously presented research by Virone et al. (2006); however, the authors here used Bluetooth technology. Bluetooth is more preferable for data security, but it may impose much more interference caused by different factors and the data transfer rate is lower.

A multiple-patient wireless sensor application presented by Aminian and Naji (2013) consisted of sensors and actuators in a virtual hospital centre to monitor the heartbeat, temperature, and motion of a pregnant woman and her baby. Based on the gathered results, this application promised the reduction of energy consumption which is related to network lifetime and speed of the data transmission. Furthermore, this architecture included the patient-physician communication through a GSM modem, which enabled the possibility to send SMS in case of emergencies. However, the proposed system was tested in an improvised hospital centre without any obstacles like walls or doors.

Further to these studies, in the literature are proposed various sensor-based fall detection systems (Abbate et al., 2012; Iliev & Dotsinsky, 2011; Mao et al., 2017). These research studies aimed to improve patients’ lives by using pervasive sensing and computing. All these present examples of the application of the Internet of Things (IoT) to track, record, analyse and transmit patient-related information to monitor better and offer healthcare services also from a distance. Hence, in the following subsection, existing sensor-based platforms for continuous and remote monitoring of chronically ill patients specifically, are presented.

2.4.2 Monitoring chronic diseases through sensor-based platforms

Considering the benefits of sensor-based networks in healthcare, there have been several studies that have proposed architectures, platforms and remote communication systems to provide better healthcare services to chronically ill patients. The iRhythm (2021) developed a product named ZIO patch for detecting heart arrhythmias. Hence, the patient should push a button in case of an arrhythmia, and all the gathered data until that point would be forwarded to the medical personnel in the form of a report (Higgins, 2013). Holter monitors presented another wired-based eHealth platform (American Heart Association, 2015) for remote and continuous (limited to several days based on battery life) monitoring of heart rate and blood pressure. In the literature, various studies compared the performance of the ZIO patch with the Holter monitors (Barrett et al., 2014; Turakhia, 2013), which both provide heart monitoring. Holter monitors use web platforms for presenting patient data, and wired electrodes attached to a patient's chest to record heart rate, and other units attached to a patient's hand when recording blood pressure. These studies concluded that the majority of patients who have worn Holter monitors for a day and those that used ZIO Patch for two weeks preferred the latter one. However, considering developing countries the relative cost of the ZIO Patch, around $500 (Biotechsf, 2014), is probably high as, in some countries, it is higher than their average salary, i.e., in Kosovo, in 2021 the average monthly gross wage was €466 (ASK, 2021c). The working logic of the ZIO patch, on the other hand, may be a bit confusing as the patient may not understand when he/she is having arrhythmias to push the button, or there may be an emergency and the patient may not reach to press the button at all and the medical staff will not get his/her data.

Nuvant and Avivo are devices that are very similar to the already presented concepts of treating and monitoring cardiac arrhythmias or atrial fibrillation (Diagnostic and Interventional Cardiology, 2009). Cardionet MCOT (Cardionet, 2021) developed another product to monitor the heart of a patient which also uses wires connected to the processing unit, and three electrodes attached to the patient body, around the heart. However, its cost around $750 per patient, is even higher than the cost of the ZIO patch. SensiumVitals (Atkinson, 2014) presented another device in the form of a patch used to monitor heart rate, respiratory rate, and axillary temperature. The sensing parameters differed SensiumVitals from the ZIO patch and Nuvant. This device is used within the hospital area to send data signals to the nurses wirelessly.

Most of the above-mentioned applications are used mainly for heart monitoring and are in the form of patches. There are also sensor-based platforms in the form of shirts. Smart Vest, is one of these and it presents a system architecture that, besides the heart rate, can also monitor blood pressure, galvanic skin responses, and body temperature (Pandian et al., 2008). Sardini and Serpelloni (2014) also proposed a T-shirt for monitoring vital parameters, such as heart rate, acceleration and respiratory rate. These two monitoring shirts differ in the types of parameters that they monitor and the communication technologies that they use.

Weber et al. (2013) proposed a wrist blood pressure measurement device. The proposed device can record continuously the blood pressure values using a DOPPLER ultrasound sensor, and a voice coil actuator which is used to change the pressure in a balloon. This system architecture was tested using a blood pressure simulator. The Advanced Medical Monitor (AMON) presented a system architecture that can monitor blood pressure, physical activity, oxygen saturation, body temperature, and record an ECG (Lukowicz et al., 2002). However, the gathered data were not transmitted continuously. Similarly, Nagae and Mase (2010) proposed a system architecture that is suitable to monitor respiratory rate, oxygen saturation, or coughing activity. The testing of the proposed system was completed using experimental data, and not real-time data.

The above-presented platforms are all sensor-based devices used in various healthcare disciplines to provide remote and continuous monitoring of chronic parameters. Table 2.4 presents a brief overview and critical analysis and comparison of existing sensor-based platforms for monitoring chronically ill patients proposed in the literature. The similar approaches presented in Table 2.4 are elaborated in terms of the parameters that they monitor, system highlights and other features that they offer, and limitations of the proposed platforms and what differs them from the sensor-based architecture proposed in this thesis.

Table 2.4 Synthesis of sensor-based platforms for monitoring chronic parameters

Project/Application name	Monitoring parameters	System highlights	Disadvantages	Comparing with the sensor-based prototype proposed in this thesis
Smart Vest (Pandian et al., 2008)	Heart rate (can record electrocardiograms-ECG), blood pressure, body temperature, record photoplethysmography (PPG) and galvanic skin response.	A washable shirt that can continuously record physiological signals. It can monitor several parameters through a single device without user interaction. The prototype was tested in a clinical environment using 25 males. The system had different accuracy levels compared to traditional models.	A prototype system. Wearable data acquisition and processing hardware are too big and not so practical to wear. The battery of the hardware processing unit can last only 4.5h when it is fully charged.	The proposed prototype provides information also on the user's ECG, PPG, and galvanic skin response. Nevertheless, this sensor-based wearable shirt did not offer continuous monitoring. From the methodological point of view, the authors did not consider users' attitudes to wearing such shirts, before proposing the platform. However, the study was clinically validated with 25 users that carried out the prototype.
AMON (Anliker et al., 2004; Lukowicz et al., 2002)	Heart rate, blood pressure, oxygen saturation (SpO2), temperature, activity and a one lead ECG.	A wrist-worn monitoring system that is designated for high-risk cardiac/respiratory patients. It can perform analysis of gathered data online and present them in the appropriate format. It can monitor several parameters through a single device (which weighs half of the grams that the Smart Vest's hardware processing	Gathered data were not transmitted continuously to monitoring personnel (3 times per day if everything was ok, or immediately if all parameters were out of the normal range). Pandian et al. (2008) reported inconsistency in gathered	The proposed prototype provides information also on the user's one lead ECG. It consists of a single device that has all the sensors, processing and communication components incorporated. The values of the blood pressure and ECG are measured three times a day (not all the time) or at the request of medical personnel.

		unit). The performance of the AMON was tested by a medical study of 33 participants. The system had different accuracy levels compared to traditional models.	medical data while using AMON.	The proposed system was medically validated with 33 volunteers, that worn the device for 70 min. Nevertheless, the final results showed that some patients had insecurities and complaints.
HealthGear (Oliver & Flores-Mangas, 2006)	Blood oxygen and pulse levels while the user is sleeping.	The HealthGear presents a set of sensors that use Bluetooth technology to send sensed data to a mobile phone. The gathered data are stored, transmitted, analysed, and presented to the user in the appropriate format. The system was tested using 20 volunteers.	It uses Bluetooth technology which may impose interference caused by various factors. The data rate of this application was low (9600 bps). Batteries (two AAA) of the HealthGear can last 12 hours.	The proposed system can run continuously for a limited time interval of 12 hours. The authors evaluated the HealthGear with 20 volunteers who used it for one night, and after that, they filled a questionnaire to rate its usability. Nevertheless, similarly, as with the AMON and Smart Vest, healthcare professionals were not reported to have been part of the design, proposal, nor evaluation phases of the proposed systems.
LifeShirt (Halin et al., 2005)	ECG and oxygen saturation.	A wearable monitoring system that can record ECG and oxygen saturation. It can record these data and store them for later access.	LifeShirt was designed to monitor patients in the operating room but not in real-time. It used conventional electrodes and did not provide an online analysis of data. According to Pandian, et al.	The proposed sensor-based system is designated also for use in a hospital operating room environment. The LifeShirt was medically evaluated by 10 healthy volunteers for 8h, and another 10

			(2008) the ECG recording of outdoor participants was affected by the baseline wander, which created difficulties in analysing ECG.	hospital patients. However, the collected data was reported to vary in quality. According to the authors, their biggest problem was monitoring respiratory function.
AliveCor (Paul et al., 2012)	Heart monitoring.	An iPhone-based ECG reader that can monitor and record users' cardiac rhythms, as well as send their information to healthcare providers.	It does not provide continuous recording of a patient's physiological data. AliveCor is available for a set of smartphones and was not compatible with all of them.	AliveCor enabled monitoring of a single vital sign, the ECG recording. This sensor-based platform was developed by a cardiologist; however, no information was reported on the user's acceptance before proposing it.
ZIO patch (Higgins, 2013)	Heart monitoring.	It presents a heart monitoring patch that can record patient data continuously for up to 14 days. Patients can use it during exercises while sleeping, and bathing (under certain conditions).	A patient's vital signs were recorded for a maximum of 14 days. Its costs may be high considering developing countries' economies (refer to 2.3.4 Cost analysis).	Zio Patch enabled monitoring of a single chronic parameter, the heart rate. The recorded patients' vital signs, were not transmitted in real-time (Dar et al., 2018).
Holter monitors (Barrett, 2014)	Heart monitoring and blood pressure.	Holter monitors used a web platform to present patients' data, and wired electrodes were attached to the patients' chest or arm to record medical data. It enabled continuous monitoring of	It presented a wired architecture with electrodes that cause discomfort for the user and difficulty to wear for a longer interval of time. Holter monitors did not transmit gathered data in real-time.	Holter monitors did not enable continuous, remote monitoring and access to a patient's vital signs. Hence, the patient had to bring back the device to the medical centre, for the HCPs to connect it with a PC or laptop, and

		heart rate, and blood pressure for a limited period of time.	According to Higgins (2013), Holter monitors presented a slow communication system. The recording interval depended on battery life (i.e., monitoring of up to 7 days).	read the recorded patient's vital signs. It could provide monitoring to a limited period of time (up to 7 days),
Cardionet MCOT (Cardionet, 2021)	Heart rate.	MCOT enabled the continuous recording of heart rate and real-time transmission of the gathered results. It had a sensor attached to a patch and a mobile unit used to transfer gathered sensor data.	The sensor device and the mobile unit should not be at a greater distance than 30ft from each other. The patient needed to charge both units separately for a maximum of 5 days.	It used Bluetooth technology with a short range of communication between the sensor and the mobile unit. The patient could wear the platform for a maximum of 5 days and then he/she needed to charge it and change the patch (remove the old one and put it on again). The recorded patient vital signs were not transmitted in real-time (Dar et al., 2018).
ECG Watch (Randazzo, Ferretti, Pasero, 2021)	Heart rate.	ECG watch presents a non-invasive single-lead ECG monitoring platform. It enables remote sharing of the gathered data through a mobile app.	No information is provided on the battery life, even during the testing phases of the prototype (only that the patient needs to charge it with a USB cable). The experimental study consisted of only 30 participants of young-middle-	The proposed prototype enabled the monitoring of ECG and could detect atrial fibrillation through an algorithm implemented by the authors. However, other parameters related to chronic conditions were not mentioned. Moreover, no information on the battery life or mode of wearing the device (i.e., artefacts when

			ages (25 – 35 years old) with no cardiac problems.	there is no skin contact) was provided.
Tele-ECG Monitoring System (Ozkan, et al. 2019)	Heart rate.	It consists of a wearable ECG monitoring platform that enables recording of heart rate and remote communication of gathered data, between the patient and clinician.	The patient needs to press a button if he/she is not feeling good which, in critical situations, the patient may not be able to do it.	The tele-ECG monitoring presents a prototype that is experimentally tested with 30 volunteers of young-middle-ages (25 – 50 years old).
SensiumVitals (Hernandez-Silveira et al., 2015)	Heart rate and respiratory rate.	SensiumVitals presented another device in the form of a patch used to monitor heart rate and respiratory rate. This sensor-based platform aimed to enable the in-hospital patients to feel free of wires, and move independently within the hospital environment while being monitored.	This device was designated for use within the hospital area. Furthermore, it offered only 5 days of battery life.	The SensiumVitals presented a sensor-based platform developed for frequent surveillance of in-hospital patients. Hence, it was limited in the monitoring interval of 5 days and the patient needed to be within the hospital area. As such, this system did not provide distance-based monitoring.
Wrist blood pressure measurement device (Weber et. al., 2013)	Blood pressure.	It presented a wrist blood pressure device that could record blood pressure values.	The proposed wrist-worn prototype did not consist of a single device. Furthermore, it was tested using an experimental setup, and the values of the blood pressure were changing when the user was lifting the arm.	The proposed sensor-based prototype enabled monitoring of a single vital sign, the blood pressure.

HeartGuide (Omron, 2021)	Blood pressure.	HeartGuide presents a wrist monitor that measures blood pressure.	This product is available in the U.S. market. Moreover, it uses Bluetooth technology for communication with the mobile app to share recorded patient information. Cannot be considered a cuffless platforms as it has an extra-stiff band included in the wrist.	The HeartGuide is a product designed for developed countries, considering also that it costs around $500. Moreover, it enables monitoring and recording of information on blood pressure, and no other chronic parameters, such as oxygen saturation or heart rate.
UAHealth (Milošević et al., 2011)	Weight, physical activity and heart activity.	The UAHealth presented a mobile health application (iOS-based), used for monitoring patients' weight, physical activity, and heart activity. Gathered data were uploaded to the server and accessed by healthcare professionals.	Did not use real-time communication. Thus, gathered data was transmitted when the device was connected to the Internet. It presented a prototype designated for iPhones.	The recorded information using the UAHealth could be accessed by the user, healthcare professionals, or other individuals authorized by the user. There is no information regarding the user acceptance or evaluation of the proposed sensor-based prototype.

The sensor-based platforms presented in Table 2.4 enabled the recording of various vital signs that are usually monitored in a chronically ill patient. They differed from the sensor-based prototype presented in this thesis (SBNHealth, chapter 6) in the vital signs that they monitored, technologies that were used to implement and run the proposed prototypes, methodologies used, evaluation methods, and designation (some of the above-mentioned platforms were designated for in-hospital use).

While reviewing all the platforms presented in Table 2.4, it was not possible to find reports related to them using a theoretical framework or a technology acceptance theory to investigate users' acceptance or their attitudes before implementing the platform. All of them reported technical or experimental studies with volunteers to evaluate the validity of the proposed prototype or product, but not its usability. Hence, the following section (2.5) provides more details on the technology acceptance models used as theoretical frameworks elaborated throughout this thesis. This is followed by a further detailed and critical analysis of the studies that exist in the literature on the methods that they have used before or after proposing their sensor-based platforms in section 2.6. Hence, another detailed table (Table 2.5) will present and critically review the similar approaches that performed an investigation or evaluation study of user attitudes of sensor-based platforms for chronic conditions.

2.5 Review of technology acceptance models as theoretical frameworks

The successful implementation of a sensor application will be highly dependent on users' adoption and their perceptions. Issues like application accuracy, data security, and integrity, patient privacy, and control over gathered data, are some of the aims that e-health products should comply with. The study from the U.S. Department of Health and Human Services (2006), found that users' serious concerns were related to the attitude to use information technology, data privacy, and their opinions related to the already implemented e-health applications. Therefore, this report proposed that the architecture of a sensor-based application should be designed according to users' requirements and it should follow a user-centric development.

To understand, describe and predict a user's acceptance and adoption of technology, various models and theories are presented. The two general theories that describe human decision-making, behaviour, and action initiation are considered to be the theory of reasoned action (TRA; Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975) and the theory of planned behaviour (TPB; Ajzen, 1985, 1991). These theories present the ground base for the theoretical models of technology acceptance as described below. This thesis combined concepts of various technology acceptance models (i.e., TAM2, UTAUT and TTF) during the empirical studies (chapter 5 and 7), such as: perceived usefulness, perceived ease-of-use, job relevance, performance expectations, social influence, truth-telling, and the output quality or impact of the digital technology on healthcare professionals' everyday work. In this context, the model that included most of the above-mentioned variables, was TAM2 (subsection 2.5.3). Hence, the theories that were applied to this study's results were related to the organizational adoption of digital technology in the healthcare setting and healthcare professionals' acceptance and perceptions related to the sensor-based platforms. These variables are briefly presented in the next subsections through their corresponding models.

2.5.1 Theory of reasoned action and theory of planned behaviour

The TRA aims to explain the relationship between the behaviours, attitudes, subjective norms and intentions to perform an action in a certain way. Hence, this theory is mainly used to investigate and predict how a person will act based on attitude and behavioural intention (LaCaille, 2013). This theory considers that an intention to engage in a certain behaviour may be the best predictor to understand whether an individual is engaging or not in that behaviour, where the intentions are affected by the attitudes and subjective norms. An example could be: the more positively a healthcare professional regards monitoring chronically ill patients using sensor-based platforms, and the more he/she perceives this action will be important to his/her patients, colleagues, healthcare centre, or society, the more likely he/she is to form intentions to better engage in using sensor-based platforms for remote monitoring.

Nevertheless, Ajzen (1991) added the importance of perceived behavioural control as a new variable to the existing TRA model and extended this, to the theory of planned behaviour as presented in Figure 2.11.

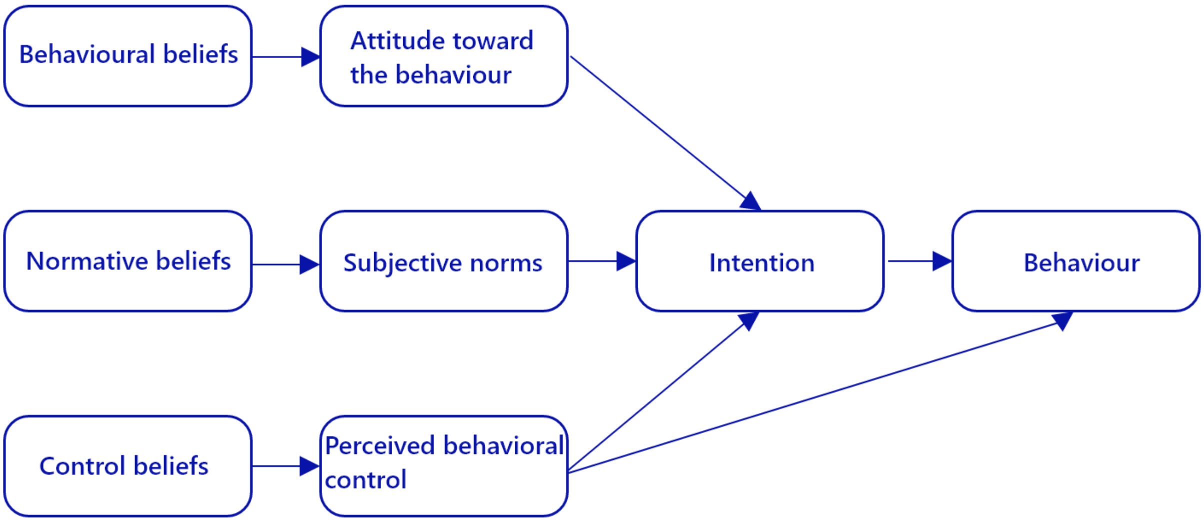


Figure 2.11 Theory of planned behaviour (adapted from Ajzen, 1991)

As presented in Figure 2.11, the TPB uses behavioural beliefs, normative beliefs, and control beliefs to investigate or predict an individual's intentions and behaviour towards a specific action. Similarly, as in the TRA, the central factor in the TPB relates to the individual's intention to perform a specific action (i.e., apply sensor-based platforms for remote monitoring of chronically ill patients). The intentions in this context represent motivational factors that influence a behaviour (Ajzen, 1991), e.g., how much are HCPs willing to try, or how much are they willing to spend time and efforts on training, to learn how to use SBN (in this case the specific behaviour). According to Ajzen (1991) the stronger an intention to perform and engage in a behaviour, the more likely will be its performance, considering that there are required opportunities and resources (i.e., networking and hardware infrastructure for the sensor-based platforms to run on, monitoring devices that will provide remote communication for the healthcare professionals, and similar prerequisites).

The TPB is considered as a model widely used (Yarbrough & Smith, 2007), however, when comparing technology acceptance model (TAM; as a derivation of TRA) and predictors of TPB for the adoption of digital platforms, various studies (e.g., Mathieson et al., 2001; Venkatesh et al., 2003) described TAM as a more approximate predictive model of technology acceptance, and TPB to be a more general model. Therefore, the following subsection will provide more details on the TAM concepts, its extensions, and the correlation of these predictors to an individual's behaviours.

2.5.2 Technology acceptance model

Technology acceptance is defined as a user's intentional or voluntary will to use a technology (Davis et al., 1989). TAM was the first model of technology acceptance derived from the TRA theory presented by Davis (1989), and was used to assess the willingness of individuals to adopt new digital systems of that time, such as the electronic mail system (Alwahaishi & Snasel, 2013).

TAM, depicted in Figure 2.12, is considered to theorize users' intention to use a digital platform that is characterized by two main factors: their belief that using such a system will have a positive effect on their job performance, defined through the concept of perceived usefulness (PU), and system usage of free of effort, defined through the concept of ease-of-use (PEOU) (Dünnebeil et al., 2012; Mohamed et al., 2011). Hence, the perceived usefulness defines an individual's perception that using a digital platform will have benefits and be advantageous compared to the current practice used. While the perceived ease of use defines an individual's perception that the utilization of digital technologies will be effortless, and relatively painless (Davis et al., 1989). The relation of these concepts and their influence on attitude and behaviour intention are presented in Figure 2.12.

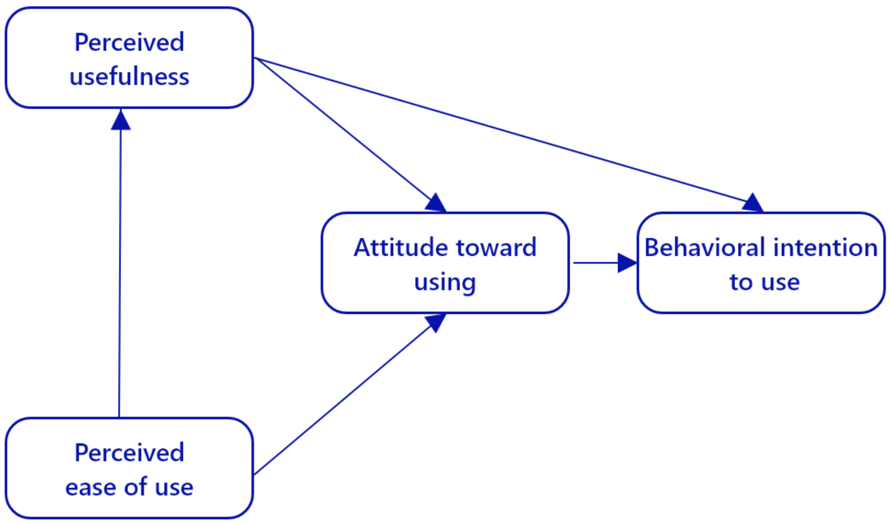


Figure 2.12 The technology acceptance model (adapted from Davis et al., 1989)

As seen in Figure 2.12 the modern variations of TAM have a direct relationship between the behavioural intention and the perceived usefulness, while the perceived ease of use has an influence indirectly through the PU and attitudinal variables. Nevertheless, TAM has a limitation in considering the influence of other external variables and barriers or challenges of technology acceptance. As various studies have also suggested, the influence of external variables should not be ignored as they can provide a more accurate evaluation and prediction of technology acceptance (Burton-Jones & Hubona, 2006; Yi et al., 2006). Therefore, a need to extend TAM emerged, as presented in the following subsection through its extensions.

2.5.3 Technology acceptance model 2

Seeing the limitation of the previous TAM model, Venkatesh and Davis (2000) extended it by adding two additional processes that influence an individual's engagement in technology adoption and named it TAM2. Hence, TAM2 involves the social influence processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, and perceived ease of use), as shown in Figure 2.13.

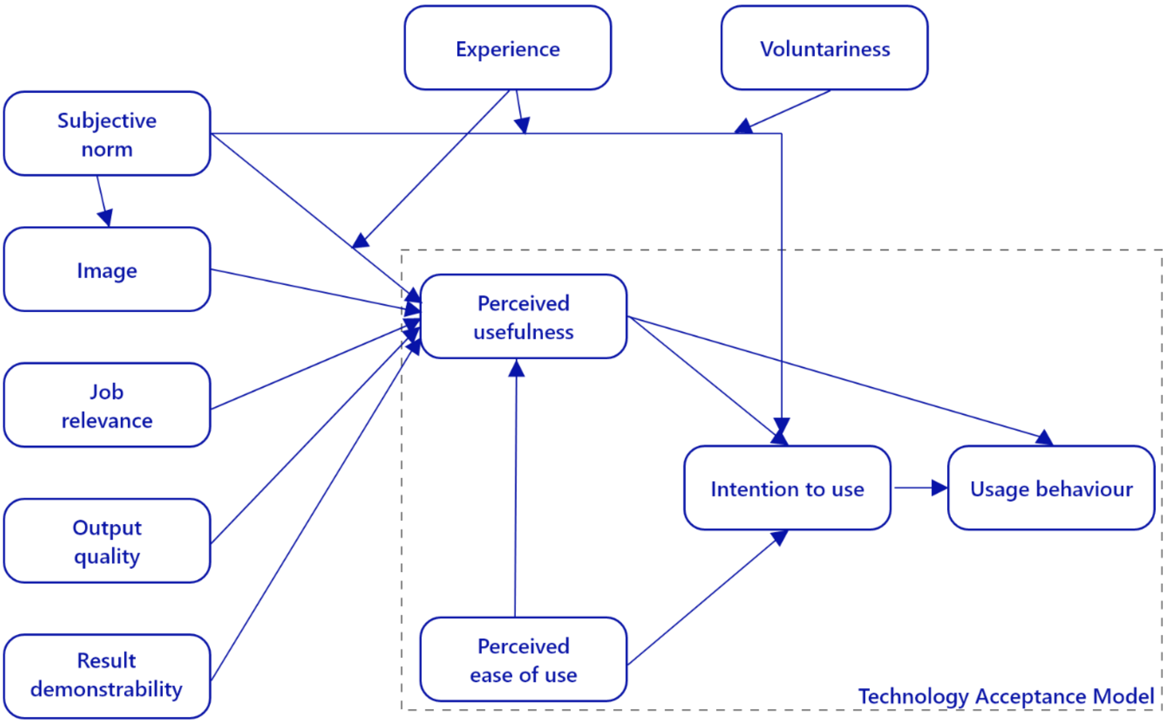


Figure 2.13 Technology acceptance model 2 (adapted from Venkatesh & Davis, 2000)

The new concepts proposed in the TAM2 provide more evidence and enable a more detailed analysis of the factors that may influence an individual's acceptance and adoption of new technologies. According to Venkatesh and Davis (2000), the additional processes that TAM2 has, aim to improve the explanatory aspect of the model. As shown in Figure 2.12, the TAM2 is built upon the basic TAM concepts, the PU and PEOU, and in addition, it contains social influence processes such as subjective norms and image, and cognitive instrumental processes such as job relevance, output quality, and result demonstrability. The experience and voluntariness were considered as concepts that may contribute to the influence of subjective norms. In this way, TAM2 considers more aspects and indirect effects to predict usage intentions.

Venkatesh and Davis (2000) provided detailed explanations of the concepts included in the proposed TAM2 as follows:

- **Perceived usefulness**, defines an individual's perception that using a digital platform will enhance his/her job performance;
- **Perceived ease of use**, defines an individual's perception that using the system will be effortless;
- **Subjective norm,** defines other peoples' influence in an individual to use or not a system,
- **Image**, defines the degree that the usage of digital technology is perceived to enhance an individual's status in the social system;
- **Job relevance**, defines the degree to which an individual perceives that the system applies to his/her job;
- **Output quality**, defines the degree of how well the system performs predefined tasks and the degree to which those tasks fit an individual's job goals;
- **Result demonstrability**, defines the degree to which an individual perceives that using the system provides results in the job performance and output quality;
- **Voluntariness**, defines the extent to which individuals perceive the adoption of technology to be non-mandatory;
- **Experience**, presents a moderating variable in TAM2, which means that it can affect a relationship between the constructs of the model. As seen in Figure 2.12, the experience can influence the social influence processes over time, i.e., the increased system experience over time may influence subjective norms.

Hence, the TAM approach presents the basis (as seen with the TAM2), wherein new additional concepts can be incorporated as long as these constructs are theoretically relevant and their involvement in the theoretical model is validated and they present an evidence-based decision. Similarly, in the literature, there are proposed other technology acceptance frameworks as elaborated in the following subsections.

2.5.4 Unified theory of acceptance and use of technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) presents a unification or a combination of eight theoretical models of technology acceptance including TAM. According to Venkatesh et al. (2003), the UTAUT model presents a useful framework for individuals that need to evaluate the likelihood of success of new systems and it helps them to understand the factors that may drive the adoption of the new technology. Hence, this model considers seven variables to be a significant determinant of behavioural intention to use digital technology (Venkatesh et al., 2003), as shown in Figure 2.14.

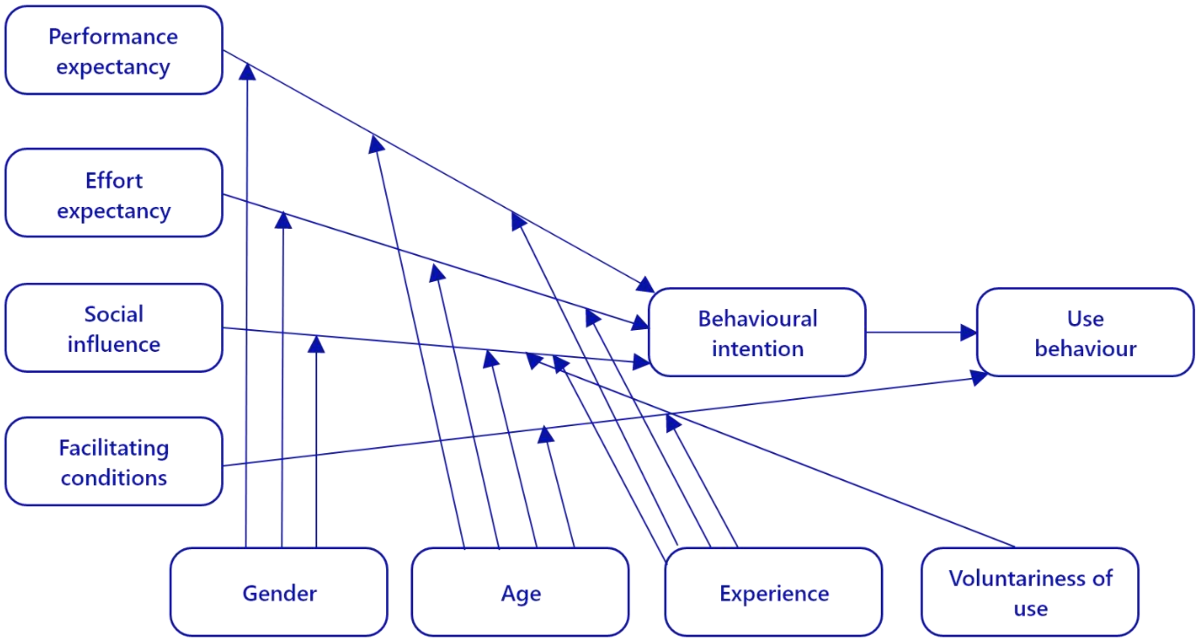


Figure 2.14 Unified theory of acceptance and use of technology (adapted from Venkatesh et al., 2003)

Four out of seven concepts that UTAUT presents are considered as direct significant determinants of user acceptance and behaviour: effort and performance expectancy, social influence, and facilitating conditions, as presented in the left side of Figure 2.14. These variables emerged from the empirical analysis presented in Venkatesh et al. (2003). The same report defined the constructs of the UTAUT as follows:

- **Performance expectancy**, defines an individual's perception that using digital technology will help attain gains in job performance;
- **Effort expectancy,** defines the degree of perceiving the system ease to use or not;
- **Social influence,** presents a direct determinant of behavioural intention and is defined as an individual's perception of whether others in higher positions believe that he/she should use the new system;
- **Facilitating conditions,** defines an individual's perception that there exists an organizational and technical infrastructure to support the use of the new system;
- Moderate variables are considered age, gender, experience, and voluntariness of use, similarly as in TAM2.

The UTAUT has been criticised for including many independent variables that influence behavioural intention to use new systems (Bagozzi, 2007). Nevertheless, Venkatesh et al. (2003) considered the UTAUT to be more robust than the previous models for predicting and evaluating the technology acceptance of new platforms. Further to this, the UTAUT has also been tested in the healthcare context (Dünnebeil et al., 2012).

2.5.5 Task-technology fit

The task-technology fit (TTF) model presents another framework for predicting an individual's perceptions towards using new digital technologies, however from a different perspective compared to the models discussed in the previous sections. The TTF highlights the importance of the fit between the system and an individual's tasks for enhancing job performance (Goodhue, 1995). Hence, this model aims to predict the degree to which a new digital platform can assist a user in performing his/her predefined tasks. Further to this, Goodhue and Thompson (1995) suggested that the TTF model may be considered as a diagnostic tool for understanding and evaluating whether the new digital systems are meeting users' needs for the specific organization.

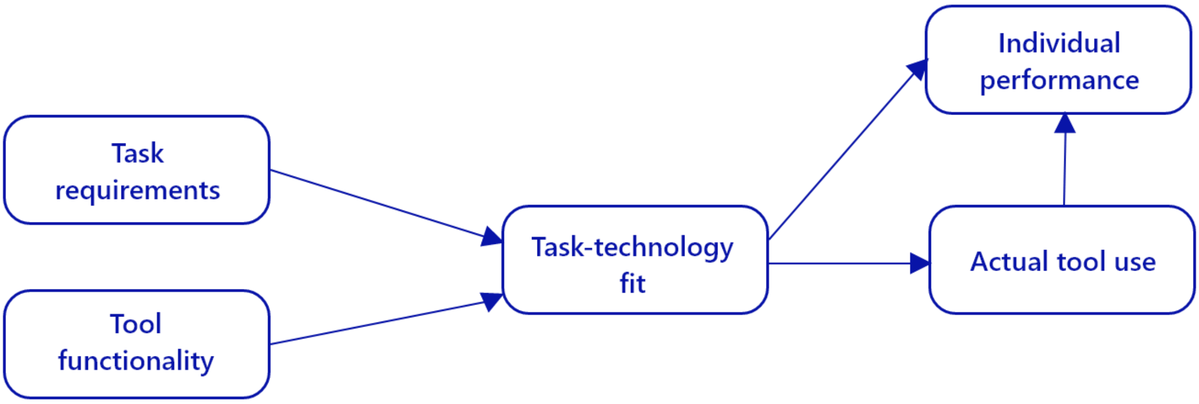


Figure 2.15 A basic task-technology fit model (adapted from Dishaw & Strong, 1999)

As shown in Figure 2.15, Dishaw and Strong (1999) visualised the TTF in a basic structure in which a system's functionalities and an individuals' tasks present the key variables that predict and enable a user to engage and use the new digital platform. It is worth mentioning that TTF, like TAM, was extended and analysed further in various studies (Lin et al., 2020; Rai & Selnes, 2019) to provide a better understanding of tasks or to include more dimensions related to a system's performance and its functionalities. According to Spies et al. (2020) TTF presents a widely known theory that was applied in a wide range of studies, with the majority of them being in the healthcare setting.

All the models described until now present examples of technology acceptance frameworks that may be applicable for understanding healthcare professionals' attitudes and adoption of sensor-based platforms in healthcare settings. Therefore, this study has used various concepts presented here to explore, and understand HCPs current practices, and their attitudes towards SBNs as discussed in chapter 5 (5.6 Discussion) and chapter 7 (7.6 Discussion).

2.6 Similar approaches on user acceptance of SBN platforms

In the literature, various studies have investigated healthcare professionals' acceptance of telemedicine using different models and constructs (Chau & Hu, 2002; Gagnon et al., 2003). In this context, to provide more evidence and enable an in-depth understanding of the healthcare professionals' attitudes towards digital technologies, various studies have used or proposed variations of the technology acceptance models (Yarbrough & Smith, 2007).

Asua et al. (2012) performed a quantitative research design using a questionnaire formulated based on the extension of the TAM. The aim was to investigate healthcare professionals' acceptance of telemonitoring for their chronically ill patients in Bilbao Primary Care Health Region, Spain. This study concluded that facilitating conditions, the compatibility of telemonitoring with clinical practices, and the perceived usefulness were the most important aspects for the healthcare professionals' intention to use a telemonitoring system. Similarly, Gagnon et al. (2012) used a questionnaire based on TAM to investigate factors that influence the decision of healthcare professionals (nurses and doctors of the cardiology, pulmonology, and internal medicine departments of a tertiary hospital) to use a home telemonitoring clinical trial system, in the Basque Country, Spain. This study concluded that factors that may influence their acceptance of telemonitoring include appropriate organizational infrastructure, support, and training for using the proposed platform. Saigi-Rubio, Torrent-Sellens, and Jiménez-Zarco (2014) reported very similar results in their research on the acceptance of telemonitoring in a sample of Spanish, Colombian and Bolivian physicians. This study used TAM as a theoretical model and concluded that physicians' experience with digital technology, their optimism about digital platforms, and perceived ease of use of the proposed platforms, were the key factors that were influencing their acceptance of telemonitoring. In a later study with 398 medical professionals from a medical centre in Spain, Saigi-Rubio, Jimenez-Zarco, and Torrent-Sellens (2016) noted the importance of conducting studies before proposing and using telemonitoring platforms, to identify possible barriers that influence the adoption of digital platforms.

Sharma, Barnett, and Clarke (2010) conducted focus groups with clinicians before launching a new digital system as a telehealth service in Nottingham, for monitoring patients with chronic conditions. This study found that trust (trustworthiness of the gathered data, adequate placement of the equipment by patients, and the need for technical support) and sense of security (insecurities to change current work practice, and lack of control) were two factors that may affect the adoption of the proposed technology.

Hennemann, Beutel, and Zwerenz (2016) performed a cross-sectional design study with the inpatients from various diagnostic groups including cardiology, of the German statutory pension insurance scheme. This study used an extension of UTAUT to understand the acceptance of a web-based aftercare platform. The results of this study showed limited acceptance of the proposed platform. Hence, this study suggested improving the implementation, increasing eHealth experience, providing training, and involving users (patients, healthcare professionals, or other individuals that will work with the proposed system) as collaborative stakeholders in the design and proposal processes of eHealth platforms. Vanneste, Vermeulen, and Declercq (2013) also used UTAUT to validate the constructs of their questionnaire on healthcare professionals' acceptance of a web-based system for person-centred recording and data sharing, which was distributed to 661 Belgium caregivers. The authors concluded that some critical constructs should be considered and may stimulate the behavioural intention to use the proposed web-based system, and these factors include a software's interoperability and compatibility with other digital systems, reliability, training facilities, online help, and continuous IT support.

As seen from these studies, most of them used a theoretical framework or a research method to predict and investigate users' (either healthcare professionals' or patients') acceptance of digital technologies. Nevertheless, all these studies were conducted in developed countries (according to World Bank (2021) classification), and they investigated users' attitudes either to assess a technology acceptance concept or to understand their feedback after proposing a digital solution for the healthcare domain (i.e., web-based system, telehealth services). Further studies were reviewed and summarized in Table 2.5.

Hence, Table 2.5 provides a detailed analysis of the research approaches that similar studies followed, the constructs that they evaluated, and the research instrument that they used. The goal of this review was to understand the methodologies and concepts that these studies have used either to investigate users' attitudes or to evaluate the proposed sensor-based platforms and see how they can be used to address the aims and objectives of this thesis (section 1.5).

Table 2.5 Review of similar approaches on the investigation and evaluation of user attitudes of sensor-based/digital platforms for chronic conditions

Digital platform name **Country**	**Aim of the proposed platform**	**Participants**	**Methodology details**	**Comparing with the methodology of investigation and evaluation used in this thesis**
Smart Healthcare system (Thaduangta et al., 2016) **Thailand**	The Smart Healthcare prototype was designated for elderly patients and their healthcare professionals. The vital signs, such as blood pressure, heart rate, and temperature, were displayed in a web application that was used by both parties. Healthcare professionals could access patients' vital signs and provide comments or suggestions to elderly patients. The patients, on the other hand, could see HCPs feedback and in case of an emergency, they could click a button on the web application that was triggering SMS messages to healthcare professionals' phones.	3 doctors (qualitative study) 30 elderly people, aged 60 – 80 (quantitative study)	**Qualitative study** Participants were of different healthcare areas (the first one was a general practitioner and a dermatologist, the second one was the director of Health Promotion Division: Department of Health and the third one was a paediatrician). The system was described and demonstrated to participants before the interviewing process. **Quantitative study** The authors developed a questionnaire based on TAM variables, such as PU, PEU, attitude toward usage, and behavioural intention to use.	The authors did not perform any prior research to understand users' attitudes before proposing the Smart Healthcare system. However, they did a qualitative and a quantitative investigation after proposing the system. The evaluation study with doctors included a small number of participants (only 3) who were of different clinical areas (the expertise of the participants does not relate much with the parameters shown in the system, i.e., a cardiologist could evaluate more precisely the blood pressure, or the heart rate of an elderly, than a dermatologist or a paediatrician). No information whether the users used the system before participating in the studies, or whether it was just explained/shown to them.

COPDFlix (Stellefson et al., 2014) **USA**	COPDFlix presented a prototype (web-based platform) developed to help COPD patients with online educational resources. This platform is a social media resource that contains educational videos.	3 experts, with expertise in web design and health communications technology	**Task-based quantitative study** Participants followed eight-step user-tasks guidelines. These were tasks that the participants needed to perform with the system, for example locating videos, participating in discussion threads, and posting comments. After completing the tasks, participants filled out a questionnaire based on a heuristic approach for evaluating web-based platforms. The questionnaire contained also open-ended questions.	This study consulted experts of web design and health communication technologies (mainly technical people) to evaluate the proposed prototype. Hence, it is considered as an evaluation methodology that was conducted after the proposal of the digital intervention. Furthermore, this study aimed to investigate only the usability guidelines of the proposed prototype, hence identifying and addressing possible usability violations.
Wearable-sensor-based smart-wear for health monitoring (Kim et al., 2014) **South Korea**	This study proposed an ontology-driven and interactive smart-wear with wearable sensors. The proposed system enabled real-time communication of the gathered data.	94 users	**Quantitative study** Users of the proposed smart-wear sensor-based system, evaluated the platform using a five-step Likert score of 1 to 5. A t-test was applied afterwards, to statistically analyse the differences in the evaluated data.	The authors performed an evaluation study to compare the satisfaction level of the users for their proposed prototype and another existing digital product. No prior investigation was conducted to design the smart-wear based on users' needs, nor there was information on whether the 94 participants of this study used the proposed prototype before evaluating it!
Game for Heart Failure Self-Management	A prototype of a game for heart failure (HF) self-management, was proposed as a mobile	4 research members (usability	**Qualitative study** In the first round of the usability evaluation, four research members from	The authors in this study, during phase 1: development of the game prototype, conducted an open-ended

(Radhakrishnan et al., 2016) **USA**	application. Community-dwelling older adults with HF were the target audience of the proposed prototype. This prototype did not use any sensors and did not share information with clinicians.	evaluation-first round) 7 older adults with HF (usability evaluation-second and third rounds) 20 older adults with HF (functionality evaluation)	nursing and computer game programming played the game themselves before evaluating its usability. In the second and third rounds of usability evaluation, older adults with heart failure problems played the game, under the observation of the graduate research assistant (GRA). The GRA took notes of observations using a Microsoft Excel checklist based on system-events descriptions and tasks related to playing the game. **Quantitative study** Two pre-tests were filled out by participants: a 30-item Atlanta Heart Failure Knowledge Test and a 22-item validated Self-Care of Heart Failure Index. After these tests, participants received an iPad and played the game prototype for 4 weeks. Following this, participants filled out a demographic survey and a post-game survey, where they expressed their perceptions.	survey with 34 nurses of a home health agency, to understand patients' preferences for electronic games. This research helped the authors to have a top three games, from which they chose one to implement. The rest of the research reported here was related to the usability evaluation of the proposed game for HF management.
Game blood pressure self-management	This study aimed to evaluate the impact of a game prototype for hypertension self-management	116 community-dwelling	**Qualitative study** This four-month observational study included participants divided into two groups:	This study conducted a nonblinded, randomized controlled trial, on two groups of adults with high blood pressure. Hence, this observational study was performed to understand

(Hickman et al., 2015) **USA**	on elderly patients with high blood pressure.	adults with hypertension	- Ones assigned to an attention control; they watched 20minutes educational video on hypertension - Ones assigned to the experiment condition group; were exposed to eSMART-HD game (a serious game for health referred to as electronic Self-Management Resource Training to reduce Health Disparities). All participants filled out study questionnaires of approximately one hour, blood pressure measurements, and provided feedback on the intervention condition.	the impact of the proposed game prototype on adults' hypertension and to compare it with the other group of participants that did not use the prototype.
''The Heart Game'' (Dithmer et al., 2016) **Denmark**	''The Heart Game'' was proposed as a prototype (mobile application) as part of a telemonitoring program (named Teledialog) used to help patients with heart problems, for adopting the telerehabilitation process. The Teledialog program aims to identify the needs of chronically ill patients, specifically heart patients, and their relatives, to prevent readmission and use digital technologies to design an	3 healthcare professionals and 10 patients	**Qualitative study** The authors used various data collection techniques as follows: - Interviews with 2 heart patients to see the challenges that these patients face after the discharge from the hospital; - Interviews with 2 nurses that work with heart patients to understand their perspective on the challenges that these patients face; - Observations with participants part of an exercise session with heart patients, to understand their life and treatment;	This study considered the opinions of 2 patients and 2 nurses before proposing the game prototype. Furthermore, the authors performed observations and focus group interviews to understand heart patients' daily routines and treatment processes. An evaluation study was conducted after the proposal of the prototype with 3 HCPs and 10 patients over a period of 2 weeks, to get feedback and assess the use of the proposed prototype.

	individualized rehabilitation program.		- Workshop with a heart patient and a nurse to generate ideas for the prototype; - Focus group interviews with three heart patients to understand their daily routines and get early ideas. The interviewing process was based on semi-structured interviews that lasted 45-60 minutes. The interviews were audio-recorded and gathered data were analysed using content analysis that helped in the generation of themes.	
Prototype information system (Honekamp & Ostermann, 2011) **Germany**	The authors developed an information system prototype that was used by participants to search through other integrated systems for headache problems. The aim was to use the fit between individual, task, and technology (FITT) framework for the evaluation of the proposed prototype.	70 (of 140) participants used the system	**Control group** Authors randomly selected participants for a control group in which the participant received a completed anamnesis form. The participants had to search the internet for the type of headache that was written in the anamnesis (this was one group of participants). The other group, the intervention group, used the information system prototype to search for the headache problem.	This study aimed to evaluate the proposed prototype of an information system using the FITT framework. Hence, the proposed prototype was evaluated after it has been proposed.
Anger thermometer app (Mattson, 2017)	This prototype presented a mobile application that incorporated standards of software development as well as anger	3 app developers, 1 website designer,	**Quantitative study (IsoMetrics questionnaire)** Participants followed an interviewing process related to their expertise and	The authors in this study conducted usability research with 5 expert reviewers (mainly technical people) to evaluate the already proposed anger

USA	management resources from the Substance Abuse and Mental Health Services Administration.	and 1 computer scientist.	familiarity with digital systems. Then, participants received a review of the mobile app and a paper version of the questionnaire with 75 items.	thermometer app. Hence, no prior study was reported during the design and development of the proposed digital intervention.
Usability Evaluation of Hospital Information Systems (Hamborg et al., 2004) **Germany**	This study aimed to use an IsoMetric questionnaire for the evaluation of the Hospital Information Systems.	182 participants working in the hospital (preliminary study)	**Quantitative study (IsoMetrics questionnaire)** The evaluation study of the usability of the Hospital Information Systems consisted of 106 responses (out of 182). Participants had experience in using the system.	This study used a usability questionnaire called IsoMetrics, to assess the use and application of a hospital information system. The findings showed that IsoMetrics questionnaire was a reliable technique for software evaluation in the field of health informatics.

As presented in Table 2.5 various studies used theoretical frameworks to evaluate the already proposed digital interventions. Most of the digital technologies presented in Table 2.5, were system prototypes for application in monitoring or evaluating chronic parameters, however, there were also some health information systems. Only one of the above-presented prototypes (‘’The Heart Game’’, Denmark), investigated users’ suggestions, opinions, lifestyle, and daily routines, before proposing their game application.

The review of similar approaches presented in sections 2.4 and 2.6, aimed to critically analyse and compare existing sensor-based platforms that provide remote and continuous monitoring of chronically ill patients’ vital signs, and the methodologies used, before conducting the empirical studies (chapter 5 and 7) of this thesis. Further to this, the following section provides a revised version of the literature review that follows the completion of the two qualitative studies conducted through this thesis, to re-examine the phenomena explored.

2.7 Update on research literature since the commencement of the empirical studies

The proposal, application, and adoption of sensor-based platforms is evolving fast. The increasing number of chronically ill patients, the new technological advances, improved sensitivity of sensors, increased market share, and similar factors, are affecting the sensor-based area and their application in the healthcare settings. Hence, after the completion of the empirical studies described in chapter 5 and chapter 7, there was a need to update the review of the sensor-based platforms and their acceptance and adoption into healthcare settings, to reassess and compare the findings. As such, this section presents the reports made available since the commencement of the first interview study of this thesis.

Spyglass Consulting Group (2019) performed telephone interviews over three months with one hundred clinical informatics and health IT leaders who knew about telemedicine services. This study aimed to investigate US-based healthcare providers’ challenges and opportunities of organizations to develop strategies and investments in remote patient monitoring (RPM) technologies, with the focus on chronic conditions such as CHF, COPD, diabetes, hypertension, and asthma. The findings of this study showed that 88% of hospitals and health systems planned to invest or had already invested in RPM platforms for chronically ill patients. Moreover, this study reported that healthcare providers were facing challenges related to limited budget and resources, lack of clinical programs, and data integration problems with existing clinical information systems and workflow.

VivaLNK (2019) performed another US-based survey with 100 participants of mid-ages (40 years old and above) to understand their adoption of health wearables in the form of sensory devices. This study found that 55% of participants showed a positive attitude towards using a wearable health monitoring device at home, where 64% of them confirmed they would use it if the platform would reduce the number of physical doctor visits. This is due to the cost of a physical visit, traveling distance, and attitude towards the healthcare facilities. Further to this, VivaLNK (2021) performed another survey with hospitals and clinics to understand the current state of the remote monitoring platforms. This study found significant growth in the usage of remote monitoring platforms, especially during the COVID-19 pandemic. Hence, 20% of participants confirmed to have adopted an RPM platform, and the other 23% plan to adopt one within 12 months.

Hilty et al. (2020) performed a scoping review to understand the approaches and components for telehealth among clinicians. Following a review of various studies that researched organizations and institutions mainly in the USA and Canada, Hilty et al. (2020) pointed out that collaboration between users was very needed, and also institutional expertise should be evaluated and specified in detail to ensure the quality of care and successful implementation of remote patient monitoring using sensors.

Stanhope et. al. (2016) performed a concurrent matched cohort study in the USA with patients who received remote health monitoring and those who did not. The findings of this study showed that the application of remote patient monitoring platforms can reduce hospital visits and, in this way, medical costs of chronically ill patients.

Muigg et. al. (2019) conducted an online survey with 41 practitioners in Austria to understand their readiness and attitudes towards using telemonitoring in diabetes care. This study found that participants showed a quite moderate readiness to apply remote monitoring platforms for diabetes care. The challenges mentioned in this study were related to the loss of doctor-patient communication and lack of reimbursement for healthcare professionals.

In recent years, the Food and Drug Agency (FDA) in the USA approved several sensor-based platforms that enabled the non-invasive recording of blood glucose levels. These non-invasive devices are known as continuous glucose monitors. Hence, FreeStyle Libre presented the first CGM approved by the FDA in 2017 (Cherney, 2021). This product did not involve finger pricking but it could read the blood glucose levels from the interstitial fluids in a patient's skin (Bidonde et al., 2017). The patient had to wear the sensor device on the back of the upper arm and apply it every 14 days. Nevertheless, according to FDA (2017) wearing this sensor-based platform may cause mild skin irritations, and there are risks of hypoglycaemia or hyperglycaemia if the data reported by the sensory device are inaccurate.

Eversense (2021) presented another CGM approved by FDA in 2019. Compared to FreeStyle Libre, this device has a small sensor that is implanted into a patient's skin, and there is also a transmitter that needs to be placed on top of the sensor, above the skin in the upper arm. This means that the Eversense device is placed only by medical personnel. Similarly, Dexcom G6 (2021) presented a sensor-based platform that the patient needs to wear underneath the surface of the skin, in the abdominal area. The drawback, in this case, is that the patient needs to change it every 10 days. Like Eversense, Dexcom G6 can transmit gathered patient data every 5 minutes to a smart device.

Medtronic (2021) got approval from the FDA in the USA, in 2018, for its Guardian Connect System to offer sensor-based blood glucose monitoring and insulin provision through the mounted pump on the proposed device. The Guardian Connect System is placed on the abdominal part of the body or the arm, underneath the skin. This platform has been approved for patients of ages 14 and older, while FreeStyle Libre 2 and Dexcom G6 for children age 2 and above, and Eversense for adults of ages 18 and above.

As non-invasive sensor-based platforms were proposed and were available in the market, Oikonomidi et al. (2021) surveyed 1010 adults from 30 countries (with the majority of participants located in Canada (212), France (360), USA (138), UK (108), South Africa (18), Ireland (82), New Zealand (31)) to understand the adoption of such platforms for monitoring diabetes. This study found that 65% of the participants confirmed that they would adopt remote digital monitoring platforms if they will offer health improvements, help them monitor their food, and offer real-time feedback by a medical professional. Further to this, participants pointed out that monitoring devices should be minimally disruptive.

The review of the recent literature on empirical studies related to the use and adoption of the sensor-based platform for remote and continuous monitoring of chronically ill patients indicated that:

- existing technology acceptance models should be extended to provide a more general and specific framework for healthcare setting research, i.e., consider also the design issues (Alomary & Woollard, 2015);
- healthcare providers reported similar findings as previous literature search showed, on challenges of limited budget and resources, as well as data integration problems with the remote patient monitoring platforms and existing clinical information systems and workflows (Muigg et. al., 2019; Spyglass Consulting Group, 2019);
- cost of the remote monitoring platform was considered still as the biggest challenge towards successful adoption of these technologies (VivaLNK, 2019);
- even though it is clear that RPM platforms, either as wearable devices, are not new concepts, there is still a need to understand users' motivations and attitudes to use them (Oikonomidi et al., 2021; VivaLNK, 2019);
- application of remote monitoring platforms, based on sensors, continues to be a cost-effective solution towards treating and managing chronic conditions (Stanhope et. al., 2016).

As presented throughout this section, the updated review of the literature included studies and articles related to RPM platforms based on sensors and their adoption and acceptance from its users, either healthcare professionals or patients. The following section will provide a synthesis and identify gaps in the research before the commencement of the empirical studies presented in this thesis. This means that the updated literature search presented in this section (2.7) is not included in this synthesis.

2.8 Synthesis and gaps in the research

Sensor-based platforms enable remote and continuous monitoring of health-related parameters and sharing of the gathered data to a point that is accessible from the healthcare professionals. These platforms are considered to provide a solution in monitoring patients taking into account the increased prevalence of chronic diseases, the rising aging population, and the need for healthcare services. The application of sensor-based technologies has shown to be clinically effective on the early symptom management of chronic conditions, a cost-effective solution, and a tool that may detect when a patient is deteriorating or when a symptom is becoming life-threatening. The following subsections present more in detail the key findings of the literature review, emerging issues and literature gaps, and the research question of this thesis.

2.8.1 Key findings

The review of the literature presented various studies that showed the use of sensor-based platforms in healthcare settings and their application for the monitoring of chronic conditions in various countries (Table 2.4 and 2.5). Chronic diseases, as one of the themes in this literature review (Figure 2.1), do have an impact on labour-market performance, human-capital accumulation, saving decisions, and consumption, especially for developing countries considering their limited capacities and resources to deal with the increasing number of chronically ill patients (Guo et al., 2021, Horton, 2017). Therefore, with the increasing evidence of the high number of people having chronic diseases, the policymakers need to provide solutions to the growing risk of the disease to promote economic development. Furthermore, the cost analysis that was performed using literature-based data and treatment cost of chronic diseases in Kosovo (the setting in this thesis), showed that the price rates of treatment and management of these diseases exceeded the average wages and incomes of the working population in Kosovo, as elaborated in subsection 2.3.4. Nevertheless, considering the price rates of the existing sensor-based platforms that exist in the market, it was clear that they can be considered as a cost-effective solution in providing monitoring of chronic diseases, compared to the actual costs (medical visit costs, medication costs, traveling costs, and similar) that a patient was already paying in Kosovo.

As demonstrated in Table 2.4 and Table 2.5, there are various sensor-based applications already proposed and used by individuals worldwide. Furthermore, the market share of sensor-based platforms is expected to increase further as discussed in section 1.2. Hence, the literature search for this theme (Figure 2.1) showed that sensor-based devices (either as wearable or mobile units), and remote patient monitoring technologies are increasingly being developed and used as an assessment tool and treatment modality. As Spyglass (2019) reported, the sensor-based platforms are integrated into care, and various healthcare providers plan to expand their adoption and application further.

The application of sensor-based platforms is considered to transform healthcare services from traditional methods, which are cross-sectional and involve the manual transfer of patient's data at a healthcare appointment, to a continuous and longitudinal framework (Viderman et al., 2022). Moreover, sensor-based applications enable clinical decision support and provide an automatic and remote monitoring technology. Therefore, as was also suggested in the literature review by various studies, there is a need to investigate user needs, opinions, and perceptions towards the adoption of sensor-based technologies before proposing them (Clifford, 2016; Davis, Freeman, Kaye, Vuckovic, and Buckley, 2014). As presented in Table 2.5, various studies performed investigations after they proposed a sensor-based platform, and at that point were informed about users' needs, their concerns, and possible practices that the system developers could take into account while developing the product and not after proposing it.

In order to understand users' acceptance of digital technologies, various theoretical frameworks were proposed and evaluated especially for the healthcare settings, as reviewed in this thesis in section 2.5. The proposed technology acceptance models differ from each other on the variables that they consider during the prediction of the technology acceptance. Hence, as suggested also in the literature search (Dishaw & Strong, 1999), it is important to consider a model or even combine existing models, to suit the research for the needs of the study, the healthcare setting, and users intended to apply the proposed sensor-based platform.

Research on users' adoption of remote patient monitoring platforms showed promising results in the context of their positive attitudes to apply such systems. Nevertheless, there were some insecurities, challenges, and data integration issues that were mentioned in most of the reviewed studies that need consideration (as reported in section 2.6). Hence, the following subsection provides a more detailed exploration of the emerging issues from the literature review.

2.8.2 Emerging issues from the literature review

The literature research related to sensor-based platforms and their application for remote and continuous monitoring of chronically ill patients showed a number of similar applications already proposed (Table 2.4). Further to this, some studies have investigated users' attitudes and adoption of the sensor-based platforms in healthcare settings, including monitoring of chronic conditions (Table 2.5). From this review, it can be concluded that there has been a lack of studies that proposed sensor-based platforms and investigated or evaluated their users' acceptance before proposing them, in Europe, especially in the South-East European developing countries. Hence, there is evidence that the application of sensor-based platforms will help to treat and manage chronically ill patients which is very important especially for a developing country; however, this needs to be investigated.

Consequently, is it important to investigate users' needs, and opinions before proposing a sensor-based platform. As elaborated in section 2.6, there is a need to perform studies and involve the users in the process of design, and proposal of the new digital platform, because, as Saigi-Rubio, Jimenez-Zarco, and Torrent-Sellens (2016) pointed out, this will enable the possible barriers that influence the adoption of digital platforms to be identified. For example, the system designers may have the technical skills to develop, and implement an application, however they are unlikely to understand how the platform should operate and work to suit a healthcare domain's needs. Furthermore, the existing workflows and clinical information practices should be incorporated to make easier the transition between the existing frameworks to the new digital platforms, this was one of the challenges identified in various studies presented in section 2.6. Hence, to achieve a wider acceptance, adoption, and successful implementation of sensor-based platforms, there is a need for good collaboration, thorough research, and a feasible designed application that will overcome challenges.

For investigating users' adoption of sensor-based platforms, in this case, various technology acceptance models can be used, as explored in section 2.5. Nevertheless, as the literature review showed, the technology acceptance models capture specific variables which for the healthcare context, and sensor-based platforms specifically, may not be very appropriate. Therefore, a combination of models was suggested (Dishaw & Strong, 1999) to capture different aspects of individuals' attitudes and adoption to use sensor-based platforms within the healthcare domain.

Hence, several issues emerged from the review of the existing literature on the sensor-based platforms for remote and continuous monitoring of chronically ill patients and their acceptance from the users. In order to address these issues, this thesis has defined some research questions as presented in the following subsection and has designed a research methodology to consider existing gaps, as elaborated in chapter 3.

2.8.3 Research questions

In this subsection are presented the identified research questions that will guide the research process presented throughout this thesis in the following chapters. Hence, by answering them, this study will be able to propose a unique sensor-based architecture that could be used to treat and manage chronic diseases in developing countries.

This research study aims to provide answers to the following questions:

1. In what context, will the application of sensor-based platforms help developing countries, in this study Kosovo, to treat and manage chronic diseases?
2. How can the application of sensor-based platforms address the needs of healthcare centres in a developing country (i.e., Kosovo)?
3. What may be the factors leading to the successful application of sensor-based platforms?
4. What may be the factors that may challenge the implementation of SBN in the health system of a developing country?
5. How do healthcare professionals consider the application of sensor-based networks will affect healthcare costs?
6. What should be the characteristics of an efficient sensor-based framework for healthcare in developing countries?

In this way, these over-arching research questions for this thesis are adapted for the existing literature search (Chianga et al., 2015; Davis, M.M. et al., 2014; Steele et al., 2009; Tunlind et al., 2015; Yang et al., 2015), findings of the first interview study (chapter 5), and then further research questions were developed for the evaluation interview study (chapter 7), but that they all align with the overall research questions presented above. Answering and investigating these research questions in detail will provide new knowledge of contribution in the area of sensor-based platforms for remote and continuous monitoring of chronically ill patients in a developing country in this case, and provide research results on healthcare professionals' attitudes towards the application of such technologies into the healthcare settings. Addressing these research questions will further present a basis for creating organizational and governmental policies in the remote monitoring area, Kosovo in this case as a developing country, and possibly for other SEE countries with similar characteristics.

2.9 Conclusions

This chapter has presented an in-depth literature review of the sensor-based platforms, their application in the healthcare settings, the need to provide remote and continuous monitoring for chronically ill patients, and details of a developing country, i.e., Kosovo, where the sensor-based platforms can be applied. This review provided detailed information on the networking architecture of Kosovo and the need for sensor-based platforms in health organizations. Further to this, a cost analysis compared existing patients' expenses to receive healthcare services, and the actual cost of the industrial sensor-based platforms. This cost analysis concluded that sensor-based platforms may provide cost-effective solutions considering actual patients' incomes and costs, and the assumption that the device is bought once and can be used for a longer period (i.e., years).

The review of the existing sensor-based platforms for monitoring chronic diseases, and their technology acceptance and evaluation research methods, showed that there is a need to perform research studies before proposing sensor-based application, and this with the aim of better understanding users' needs, opinions, concerns, and integrating them into the design and proposal process. Furthermore, as proposed by Dishaw & Strong (1999), a combination of technology acceptance models or constructs would enable researchers to better explore the organizational adoption of digital technology in the healthcare setting and healthcare professionals' acceptance and perceptions related to the sensor-based platforms. In this context, as there are no similar studies in the SEE and none specifically for Kosovo, there is a need to understand and evaluate the application of sensor-based platforms and healthcare professionals' readiness towards this technological innovation.

The updated literature research (section 2.7) confirmed that the technological barriers, and issues that were discussed before the commencement of the empirical research of this thesis, were still current after the completion of the research studies.

The next chapter will present the research methodology that this thesis used to address the research questions. Hence, different research approaches and methods will be elaborated and examined to identify the most appropriate one for this research.

Chapter 3 Research Methodology

3.1 Introduction

The research methodology defines a group of methods, schemes, and procedures that guide the researcher to explore, understand, gain knowledge, and explain a phenomenon under investigation. Hence, considering the identified need for research on the application and adoption of sensor-based platforms in a SEE developing country, Kosovo, as elaborated in chapter 2, and the emerging research questions (subsection 2.8.3), this chapter will present the existing research methodologies and approaches that may be applied to investigate and address the research questions.

This chapter is organized to present a brief overview of research methods, qualitative and quantitative ones, and discuss the most useful methods that apply to achieving the thesis aims. Even though this thesis used only a qualitative approach, a short introduction on quantitative research is included to be able to compare and provide arguments why it was not appropriate for this research study. Hence, section 3.2 provides an overview of research approaches and their corresponding methods, data collection tools, and data analysis process. Furthermore, the process of triangulation is also elaborated in subsection 3.2.4, considering that the within-method triangulation of the findings of both interview studies is performed (as presented in chapter 8). Other important processes, part of the research methodology, such as research ethics and research trustworthiness are discussed in sections 3.3 and 3.4 respectively. Section 3.5 presents the research conducted in this thesis by providing details on the approaches that were followed and the empirical studies that were conducted. Finally, section 3.6 concludes the chapter.

3.2 Approach to the research

This section will explore the existing research approaches, and identify the appropriate paradigm that will help answer the research questions of this thesis. Hence, the aim is to elaborate on the advantages and disadvantages of existing research methods, to help investigate the application and adoption of sensor-based platforms in Kosovo, a developing country, according to the identified needs (section 1.4).

Research methodologies may consist of qualitative, or quantitative approaches or a combination of the two (mixed methods). A quantitative approach mainly deals with the situations where the researcher investigates how much or how frequently the phenomenon is happening. Therefore, if a research question consists of how often or how many people, it is recommended to use quantitative methods (Hancock et al., 2007). The quantitative approach can be further categorized into inferential approach, experimental approach, or simulation approach.

Qualitative research, in contrast, is concerned with the subjective assessment of behaviours, opinions, attitudes, or gestures (Busetto et al., 2020; Hancock et al., 2007). In this way, the qualitative approach tries to explore peoples' experiences, interactions, or communication within a group. More specifically, it tends to understand how things are happening, how they came to a specific point, what the opinions of the interviewees are, explore new research areas, and similar. The following subsections provide more details on quantitative, and qualitative approaches.

3.2.1 Qualitative research

Qualitative research most of the time tries to transcribe words, behaviours, or gestures, into text or writing. Therefore, these are used as data instead of numbers that quantitative research uses (Braun & Clark, 2013). Qualitative research tends to investigate the social phenomenon and explain why things are the way they are, or why people do a specific behaviour; it tries to understand and explain peoples' opinions and explore their concepts or views. This is done mainly by direct interaction with participants either on a one-to-one basis or in a small group setting. As such, this approach could be used in this study considering the lack of using sensor-based platforms for remote and continuous patient monitoring, and no evidence on users' acceptance of such platforms and their readiness to provide feedback to remote-based chronically ill patients.

There are various approaches to perform qualitative studies, as presented in subsection 3.2.1.1. Further to this, subsection 3.2.1.2 shows different data collection methods used in qualitative research. The sampling approaches are elaborated in detail in subsection 3.2.1.3. Finally, the gathered qualitative data may be analysed using various approaches and tools, as presented in subsection 3.2.1.4.

3.2.1.1 Approaches

The methodological process that researchers decide to adopt is mainly affected by the type of analysis they want to make, the set of assumptions, and their research questions. In the literature, there are different approaches to qualitative research (Flick, 2007; Hancock et al., 2007) such as ethnography, grounded theory, interpretative phenomenological analysis (IPA), discourse analysis, conversation analysis, content analysis, and narrative analysis.

Therefore, the above-presented approaches mainly differ in the focus of information or knowledge that they consider important and the way they make the investigation. For qualitative research, it is worth mentioning that, nevertheless, the approach, the processes such as data collection, sampling, data analysis, and interpretation, follow one another in a repeated approach (Busetto, Wick, & Gumbinger, 2020). These processes are elaborated in the next subsection.

3.2.1.2 Data collection methods

Qualitative data collection methods usually include direct interactions with participants, either on a one-to-one basis or in a group setting. Hence, this enables the researcher to investigate in detail the opinions of participants, their attitudes, gestures, behaviour, and similar reactions related to the aim of the research. Furthermore, qualitative research enables deeper insight into the phenomenon under investigation.

The main methods of qualitative data collection are considered as follows (Flick, 2007; Hancock et al., 2007):

- Interviews

Interviews focus on participants' experiences and opinions related to the phenomenon under investigation. During the interviewing process, the researcher can address questions like "how" or "what", for example: what are the sensors, or how can we apply sensors in healthcare.

There are different forms of doing interviews such as one-to-one basis (single interviews), or group-based interviews. Interviews are usually conducted once, however, there are cases where repeated interviews are applied (i.e., in longitudinal studies). Interviews can be in the form of face-to-face meetings, by phone, or by email.

An extended form of doing interviews is called narrative interviews. The narrative interviews are focused on asking participants to tell their stories related to the investigated phenomenon. Britten (1995) discussed also structured, semi-structured, and in-depth interviews. Structured interviews present qualified interviewers with well-formed and structured questionnaires. Semi-structured interviews contain open-ended questions too, where the interviewee may express their opinions on the interviewed topic. In-depth interviews focus on one or two issues and questions are based on the interviewee's responses.

- Focus groups
  Focus groups present groups of interviews where participants can interact with each other and share ideas or discuss them. However, as there is a group of participants, the investigation becomes more complex and difficult to manage as more people are involved.

- Observation
  This presents a data collection method that does not require direct interaction with participants. As the name implies, observation is used in situations where the researcher needs to monitor participants' behaviours in specific situations (related to the aim of the study). Therefore, researchers can have data (observations) that verify the information provided during the interviews.

- Collection of documents
  This method includes the collection of materials that can provide qualitative information such as documents, diaries, photographs, websites, emails, or similar materials. In this case, the researcher can get information regarding the institution, the investigation place, or information related to the participant (i.e., by looking at photographs or investigating the documents).

- Open-ended questions
  This form of data collection may be included also in the quantitative approaches. Open-ended questions provide qualitative data which are generated from participants' responses.

Consequently, there are various data collection methods in qualitative studies that aim to guide the researcher and help in answering the research questions. Besides the data collection method, the researcher needs to identify the participants that may provide information related to the investigated phenomenon. Hence, the following subsection will provide more details on sampling strategies.

3.2.1.3 Sampling methods

The research approach is closely related to the technique of selecting the participants from a population of interest. This technique or method is known as sampling and it means that the researcher needs to select specific interviewees that provide knowledge that will contribute to the whole study. Thus, sampling focuses on finding a variety of people that will provide information so that the corresponding results that will be drawn at the end of the process, can be transferable to similar groups elsewhere.

There is not a strict line for who to select for being interviewed during qualitative research (Flick, 2007), but depending on the research study, the researcher should set some sampling criteria. The sampling strategy can be defined in advance or gradually during the investigation process. Before starting the investigation, researchers may decide to make a list of characteristics that they wish their interviewees to have, for example, specialization, health profile, age, health status, type of disease, or living area. This is known also as a criterion or quota sampling. There are also other sampling strategies as follows:

- theoretical sampling, where the researchers tend to select new case studies that will further extend their understanding;
- critical case sampling, the selection is based on the position that the interviewee may have, for example, doctors, or department managers;
- maximum variation sampling, the interviewees sampled with this strategy will have a variety of characteristics;
- convenience sampling, the researcher will more likely choose participants that are more available and have fewer difficulties participating;
- typical case sampling, interviewees in this category fit all the characteristics defined by the researcher;
- snowball sampling, the researcher invites participants based on referrals from others (i.e., one doctor refers another colleague that may contribute to the research findings).

In qualitative research, iterative sampling approaches are advised (Mose & Korstjens, 2018; Saunders, 2018). Hence, the data collection process is suggested to be conducted in parallel with data analysis, as that would allow finding more variants that may be missing in the current sample. This iterative process may continue until no new or relevant information is found and the data are being repeated throughout the data analysis process.

Sampling may be needed also while interpreting the generated results and presenting the findings of the investigation. This includes decisions on the proportion of the data that the researcher needs to analyse, or what is important to be presented to the general audience. In any case, this decision is strongly related to the study aims, the research questions, and the intended audience. Nevertheless, the researcher needs to document its sampling strategy in a way that will show clearly the importance of his/her work, and demonstrate that the whole process is not designed and performed just for data collection but provides a contribution to the investigated area. The contribution of the research, where sampling is a key part of it, is discussed further in the next subsection where the analysis of qualitative data is elaborated.

3.2.1.4 Data analysis

After considering the sampling strategy and the data collection methods, the researcher needs to think about analysing the gathered data. This means that the collected data need to be organized and summarized in a way that enables the researcher to undertake a better analysis and interpretation of them. The quantitative approach summarizes the frequencies of variables, their occurrence, and makes different statistical tests to prove variables' dependency or independence, or the probability that an issue occurred by chance or not. Conversely, the qualitative approach performs the analysis process by using gathered data to describe the problem under investigation, to provide a meaning of the phenomenon, and draw conclusions based on categorization, articulation, and summarization of the gathered data.

Nevertheless, one of the main challenges of the qualitative approach has to do with putting words into illustrative and descriptive knowledge (Black, 2006). Therefore, there is always the challenge to compress a group of the gathered data from interviews or other forms of qualitative methods, into a few lines of text which should present knowledge to the reading audience. Hence, the qualitative data analysis needs to be well-structured and have a good transcription or recording of the gathered data. According to Hancock, Ockleford, and Windridge (2007), it is very important to have an organized audit trail so that the data are protected, anonymised, and understandable if accessed by other research members. The process of transcribing the gathered data is time-consuming (it can take up to six hours for writing down a one-hour interview), it provides a lot of texts and requires the researcher's attention in describing the pauses, tone, and inflection of the interviewees.

Eisenhardt (1989) briefly discussed and argued the data analysis within case studies. He, therefore, suggested that the data should be analysed sequentially and separately, with the aim of better understanding and avoiding generalizations. Schutt (2011) also supported this conclusion by suggesting that the process of analysing qualitative data should be iterative. In this way, if the predefined questions are not working and real issues become apparent, then the researcher can change the research design.

Flick (2007) proposed categorization and coding of the gathered data as two of the most helpful methods for analysing qualitative data. The main idea is to highlight similar cases or to identify relevant parts and then compare them with other data. The content analysis presents a data analysis method in a qualitative approach, which categorizes the collected data into behavioural data, or in tables, and then summarizes them. The categorization of data or concepts from the notes and diagramming their relationships is also proposed by Schutt (2011). In this way, the data can be compared within a category (differences in the interview process), within a case (consistency in various categories), and between cases (similarities and differences of interviewees' statements).

Creswell (2007) suggested organizing the data, for example, textual information into transcripts, or image data as photographs, and then reducing the information into themes by applying repeated coding process, and finally presenting the summarized data into discussions, tables or figures. Further to this, Braun and Clarke (2014, 2022) proposed the application of thematic analysis, which has become a common approach to qualitative data analysis in health sciences. Similarly, Bryman (1992) defined the thematic approach as a method for identifying, analysing, and presenting qualitative data into themes. A theme can be a term for a group of important data concerning the research questions (Braun, Clarke, Hayfield, and Terry, 2019; Bran & Clarke, 2006). Further to this, McLeod (2015) also supported the idea of using thematic analysis and added that this is a method for researchers who know their data set and have a point in what they are trying to achieve.

Hence, themes capture important information that may help to address or answer the research questions of the phenomena under investigation. Consequently, they can be identified in an inductive way (bottom-up) or in a deductive way (top-down). Themes identified in an inductive way are strongly linked to the gathered information (data-driven approach). Conversely, themes identified in a theoretical way or deductive, are driven by the researcher's interest in the area under investigation, hence they are coded for a specific research question (Bran & Clarke, 2006). Regardless of the identification method, the thematic analysis consists of six stages of data analysis, as follows:

- **Phase 1: Familiarization**,
  The researcher gets familiar with the data while gathering them, or while transcribing, or reading and re-reading to search for patterns, and to draw ideas;
- **Phase 2: Generation of codes**,
  The list of ideas is coded into features of the data, which are grouped into relevant codes. Hence, codes present an element of the data that is interesting for the evaluation of the phenomena under investigation;
- **Phase 3: Identification of themes**,
  The generated codes from the second phase, are analysed further and categorized into potential themes. Hence, this phase consists of combining codes to form a theme;
- **Phase 4: Verification of themes**,
  Potential themes of the previous phase, are reviewed in relation to the coded information and the entire data set to generate a thematic map of analysis. Therefore, this phase consists of reviewing themes to understand whether they can be merged into one overarching theme, or they should be broken down into other themes, or sub-themes;
- **Phase 5: Defining and naming themes**,
  Includes ongoing reading and re-reading, and analysis to collate and refine the details of each theme and the story behind them, in order to provide a definition and a name for every identified theme;
- **Phase 6: Producing the report**,
  The final analysis, and the relation with the research question/s to generate a report of the analysis. As such, the final report should provide a concise, logical, and non-repetitive data story within and across the themes.

The process of analysing qualitative data may be facilitated with the utilization of various available software, for example, N6, NVivo, Atlas, or Ethnograph (Busetto, Wick, & Gumbinger, 2020; Hancock et al., 2007). These tools help the researcher to structure and organize gathered data so that the transcriptions may be easily followed and interpreted. Furthermore, Cassell and Symon (2004) proposed the usage of templates for analysing the text in thematic analysis. This method includes a group of techniques for organizing textual data and producing a list of codes that represent the identified subjects during the investigation. After that, the template is organized based on the relationship of the identified subjects or codes. In cases where both quantitative and qualitative methods are used, template analysis can provide coded themes that are similar units produced also in the case of content analysis.

The next subsection provides an overview of quantitative research. Considering that this thesis used qualitative research on both its empirical studies (section 3.5), the aim here is to provide a brief introduction on the quantitative approach and highlight the difference between the qualitative approaches used in this study.

3.2.2 Quantitative research

Researchers tend to use quantitative approaches when they aim to find out details on the frequency, or other numerical data related to the investigated phenomenon. Therefore, quantitative research studies start with a preliminary observation (Daly & Bourke, 2000) to generate theories from which the researcher can develop hypotheses, which are then tested based on the gathered data, as presented in Figure 3.1. This is known as a deductive process. The inductive approach presents a process where the researcher collects data, analysis them, and builds theories based on the gathered data. This is basically how qualitative research is carried out, and as presented in Table 3.1, the deductive and inductive approaches, are one of the differences between the quantitative and qualitative studies.

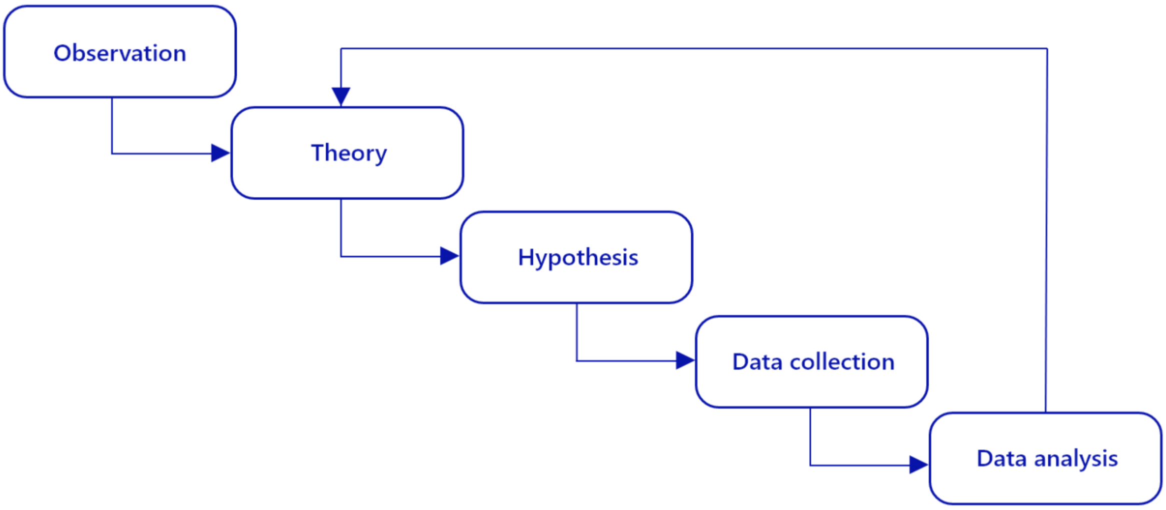


Figure 3.1 Quantitative research process (adapted from Field, 2013)

As shown in Figure 3.1, the first step is related to the literature review, exploration, and analysis of the research area to identify the gaps and define the research questions that the study aims to answer. Based on the literature review and the phenomena under investigation, in a quantitative study, the researcher should build theories and hypotheses, which are then tested through the selected data collection processes. The data analysis process for the quantitative approach consists of summaries of frequencies of variables, their occurrence, and different statistical tests to identify variables' dependency or independence, or the probability that difference or association occurred by chance or not. Finally, the analysis process will show if the gathered data support the predefined theories and hypotheses, or not.

For this thesis, it was important to present the existing research approaches and identify their differences as presented in the next subsection 3.2.3.

3.2.3 Differences between quantitative and qualitative approaches

The data structure in qualitative research will usually emerge through data analysis by using interviews, whereas in the quantitative approach there is a predetermined structure of a questionnaire. This also affects the number of participants, for both qualitative and quantitative approaches. Hence, the qualitative research aims to provide a meaning, a deeper analysis, and understanding of the phenomena under investigation from the participants' viewpoint, and using words, documents, or gestures as informative data. This justifies the fact of having smaller samples to make the research more profound. The quantitative approach aims to target a larger number of participants using the predefined questions, to generalize its findings to a wider population or group of people. Table 3.1 summarizes further differences that qualitative and quantitative methods have.

Table 3.1. Comparing qualitative and quantitative approaches (Braun & Clark, 2013; Hancock et al., 2007)

Qualitative research	Quantitative research
Gathered data are words from spoken language, observations, written documents, or images.	Gathered data are in the form of numbers.
It tries to understand the different points of view that people have for the specific phenomenon and build new theories (inductive).	It tries to find ways of describing and interpreting reality by testing theories (deductive).
The research process may be flexible and is prone to changes during the investigation process.	The research process needs to be predefined and is hard to be changed after the investigation and data gathering.
It generates a narrower set of data that presents detailed information regarding every participant (lower number of participants).	It generates a broader set of data from a larger number of participants.
Gathered data may not be interpreted numerically, therefore they are summarized into reports.	Statistical techniques are used to evaluate gathered data and to provide meaning.

Nevertheless, in different research areas both qualitative and quantitative methods are combined (Punch, 2000). The combination may be evident in research designs with the concatenation of data or methods from qualitative and quantitative approaches, or by linking the results of both methods, or by using criteria from the quantitative approach to assess the qualitative research or the other way around. Bryman (1992) and Hammersley (1996) mentioned some forms of using qualitative and quantitative approaches together, as follows:

- Through triangulation of both approaches in the context that the results of both methods should be mutually assessed and integrated (complementing the results of one method with the results of the other).
- By the means of using each methods' highlights in pursuing analysis of the other approach. This is in the context that both research methods can support each other and when combined can present a big picture of the phenomena under investigation.
- By combining both research methods as complementary research strategies, for example, quantitative findings can help solve the problem of generality in the qualitative approach, or qualitative results can help the quantitative approach to explain better the relationship between variables.

The main benefit of using mixed methods, in this case, qualitative and quantitative ones, is the data consistency and their integration with one another (Brannen, 1992). During the research process where mixed methods are used, it is important to understand the points where the data diverge, and this is better shown by triangulating the research findings. Hence, details on the triangulation process are elaborated in the next subsection.

3.2.4 Triangulation

The term comes from the use of triangulation in navigation, using two points, A and B, to reach point C. In the literature, there are various definitions of triangulation. Nightingale (2020) defined triangulation as a method used to analyse the findings of the same study that used different data collection methods. Similarly, Denzin and Lincoln (1998) referred to triangulation as the process of using multiple methods, or the process of combining different data sources, to investigate and provide a more comprehensive understanding of the phenomenon (Carter et al., 2014). Hence, the definition of triangulation may be seen in different forms, by combining different data sources (data triangulation), by using different data collection methods (method triangulation), by involving a group of researchers to investigate multiple perspectives (interviewers, observers, etc), and by combining multiple theories to interpret a single data set.

Triangulation is mainly used to increase the validity and reliability of a research study, interrogate different methods for understanding the investigated phenomenon, and create a big picture of the research problem (Golafshani, 2003; Nightingale, 2020; Strauss & Cobin, 1998). Hence, there are three types of triangulation: the convergence (it means there is a strong overlapping between the findings of two different data sets), the complementarity (the findings of two different data collection methods, inform each other and help the researcher build a big picture of the investigated phenomenon), and divergence (the research findings are flawed, and usually are treated as a different set of challenges).

There are two main methodological triangulation techniques: between-methods and within-method triangulation. The between-methods approach considers a combination of two different approaches, for example, qualitative and quantitative research methods (questionnaires and interviews used for investigating the same research problem). Conversely, within-method triangulation considers the different data collection methods within the same approach, for example, the usage of interviews and observations within the same qualitative study, or the usage of two interview studies for the same research problem as it is elaborated in this thesis (section 3.5).

3.3 Research ethics

Regardless of which approach to the research a study will use, it is extremely important to ensure the application of ethical principles in all its research activities. Hence, either using qualitative or quantitative research methods, it is essential to design and implement the research technique with respect to participants' integrity, anonymity, and ethical use of resources and research outputs. Some of the key ethical considerations when undertaking research may include respect for intellectual property, the protection and well-being of human participants, the secure handling of personal data, and the welfare of animal subjects. As Flick (2007) suggested, ethically sound research should fulfil the confidentiality and anonymity principles. Hence, the researcher should ensure the provision of true information about the purpose of the research, and ensure the interviewees' anonymity and privacy are respected.

There are various codes of ethical principles that guide a research study. Hence, the researchers should refer to ethical policies that are most appropriate for their field of research, or discipline. As Flick (2006) also stated, recently many ethic committees and ethical principles have been created to review, ensure, and authorise research with human participants. Therefore, researchers should ensure the research ethics before conducting or developing a research strategy, to comply with the ethical standards and to respect the rights, integrity, honesty, and openness of participants and their data, and in this way to avoid any risk or harm to participants.

The University of Sheffield (2021) defines a set of recommendations, policies, guidance, and detailed information for ensuring research ethics for research involving human participants or their data, through its Research Ethics Committee, in accordance with the University's Research Ethics Policy (The University of Sheffield, 2021). This makes it clear that before conducting such a study, the researcher should always obtain the research ethics approval.

The researcher should always obtain the participant's informed consent before they participate in the research, and once the participant is informed about the purpose of the study. Informed consent is recommended to be in writing, however, if that is not possible, oral consent is also an alternative. This consent is required from persons willing to participate in the study, voluntarily and freely, without being under pressure. Hence, the participant should be informed prior about the study aims, duration of the interview or questionnaire, withdrawal from the study, potential risks, benefits of the study, possible incentives, or the right to answer or not in all the required material during the research. Therefore, the University of Sheffield (2021) provides clear processes and procedures for obtaining ethics approval, before starting the data collection. The detailed steps for research ethical approval from the Research Ethics Committee within the University of Sheffield for this thesis, are elaborated in chapter 4 (section 4.3).

Research trustworthiness is another principle that researchers should consider during the design of their research studies. Hence, besides the ethical aspects, the research findings should be reliable, credible, transferable, and valid. The techniques for ensuring the research's trustworthiness are explained in the following section.

3.4 Research trustworthiness

The researcher needs to carefully consider the trustworthiness, relevance, and efficacy of the gathered data. In the literature exists various methods for promoting the quality of research methods (Drost, 2011; Flick, 2007). Validity and reliability are terms that are mainly used in quantitative research. The validity of research is related to the extent to which the research findings are accurate or, in the case of quantitative tests, the extent to which the test will measure what it claims to measure. For example, does the ampere-meter measure the electric current in a circuit? Reliability concerns the stability of measurement when the process is repeatable for different cases and the same results are obtained (Thanasegaran, 2009).

Validity and reliability are two important factors that the researchers need to consider during their research (Golafshani, 2003). However, in qualitative research instead of terms validity and reliability, there are used credibility, consistency, trustworthiness, and confirmability (Lincoln & Guba, 1985). The consistency of data, which is the term that replaces the term of reliability used in quantitative research, is achieved through verification and analysis of gathered data (Golafshani, 2003). Qualitative research also needs some form of validation or quality check. According to Lincoln and Guba (1985), the research trustworthiness will enforce the establishment of more confident research findings. Triangulation, described in subsection 3.2.4, is proposed by Golafshani (2003) as a testing strategy for research consistency and trustworthiness.

Lincoln and Guba (1985) proposed four key factors that need to be considered while assessing the trustworthiness of qualitative research, as follows:

- Credibility, i.e., should one believe in the research findings' accuracy?
- Transferability, i.e., can the research findings be applicable somewhere else?
- Dependability, i.e., in case of repeating the study, would the same results emerge?
- Confirmability, i.e., do the research findings' have a bias on research and not the researcher's motivation or interest?

Further to this, Lincoln and Guba (1985) also proposed corresponding techniques for establishing each of the four factors mentioned above. Hence, techniques for ensuring the credibility of the research study mainly suggest prolonged engagement in the context that the researcher should spend more time in the field to understand its setting, environment, context, data, and related factors that may affect the overall study. Persistent observation is another technique that orients the researcher to identify characteristics and key points of a situation that may help solve the problem. Among other techniques are also triangulation, peer debriefing, deviant case studies, and member checking (Terrell, 2016).

Techniques for determining the transferability of a study mainly suggest the description of the phenomena under study and the presentation of the results in a manner that the readers will validate to the extent to which the drawn results are valid for other times, situations, or people. Dependability may be established using external researchers to evaluate the research process and the research findings (Terrell, 2016). Therefore, the idea is to examine if the research findings and the drawn conclusions are supported by the gathered data. Finally, confirmability can be evaluated using techniques such as a confirmability audit, reflexivity, triangulation, or audit trail. These techniques suggest that the researcher should present briefly the research steps that were followed, and describe in detail the process of investigation. Consequently, various techniques and approaches can be used to prove the consistency and validity of qualitative research. The research trustworthiness is related also to research generalizability (Loh, 2013) which is an argument that quantitative researchers use against qualitative studies.

3.5 The research in this thesis

Following the rationale and motivation as discussed in section 1.4 and the detailed literature review, presented in chapter 2, a need for conducting a study to investigate users' attitudes and their perceptions before proposing a sensor-based platform, was identified (the first interview study, as presented in subsection 3.5.1). Hence, the lack of using sensor-based platforms for remote and continuous patient monitoring, and no evidence on users' acceptance of such platforms and their readiness to provide feedback to remotely chronically ill patients, lead towards a qualitative method, for both empirical studies. As Flick (2007) suggested, in cases where the phenomenon under investigation lacks previous research, the researcher needs to first elaborate and analyse the area. Consequently, a qualitative method helped to address this study's research questions (subsection 2.8.3) by investigating healthcare professionals' needs, current health practices, and opinions on a remote and continuous platform that may be applied to monitor chronically ill patients.

Hence, aiming to investigate the attitudes, adoption, and implementation of sensor-based platforms in a SEE developing country, Kosovo, and answer the emerging research questions after the literature review (subsection 2.8.3), this thesis presents the details on two empirical studies: the first interview study with healthcare professionals to understand their perceptions on using sensor-based platforms for remote and continuous monitoring of chronically ill patients (chapter 5), and the second interview study with the same participants to understand their experiences and get feedback to evaluate the proposed sensor-based prototype (chapter 7). The organization of the research conducted in this thesis is presented briefly in Figure 3.2, below.

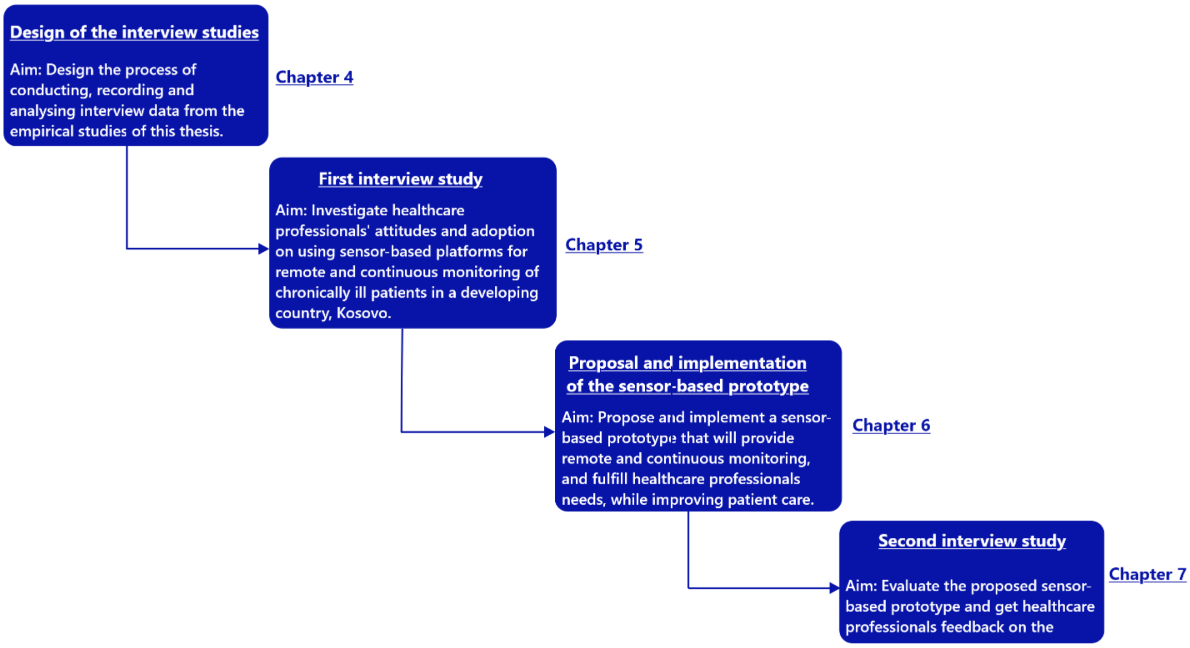


Figure 3.2 Organization of research conducted in this thesis

In between the two interview studies, this thesis includes the design of the empirical studies (chapter 4) and the proposal and implementation of the sensor-based prototype (chapter 6) used during the second interview study. An overview of the interview studies is presented in the following subsections.

3.5.1 First interview study: Healthcare professionals' attitudes and perceptions

This interview study aimed to understand healthcare professionals' attitudes and adoption of sensor-based platforms for remote and continuous monitoring of their chronically ill patients, in a developing country, Kosovo. Therefore, the application of a qualitative method helped to identify users' willingness, experience, or attitudes, and understand their opinions regarding the application of sensor-based networks for continuous treatment and monitoring of their patients. The findings of this study were discussed using different technology acceptance concepts (as described in section 2.5) applied for the healthcare setting. Furthermore, the results from the first interview study provided the ground base for proposing, designing, and implementing the sensor-based prototype in this thesis (chapter 6). Chapter 5 provides the details on the design, methodology, and findings of this study.

3.5.2 Second interview study: Evaluation of the proposed SBNHealth prototype

Following the first interview study, which provided useful information on healthcare professionals' needs, practices, and possible challenges, to provide continuous and remote monitoring, a second interview study was undertaken. Hence, the findings of the first interview study revealed that HCPs did not have experience with sensor-based platforms for real-time and distance-based monitoring of their patients, and some research questions of this thesis could not be answered in detail. In this way, the proposal and implementation of the sensor-based prototype (sensor-based health monitoring, SBNHealth) facilitated the investigation process in this second interview study, as healthcare professionals could perform tasks with the proposed prototype that enabled them continuous and remote monitoring of a patient. Consequently, the findings of the second interview study provided an evaluation of the proposed SBNHealth, and enabled more specific comments and feedback from healthcare professionals, considering that now they could interact with a sensor-based platform. This enabled a wider and more complete picture of acceptance and adoption of a sensor-based prototype for remote and continuous monitoring of chronically ill patients in a developing country, Kosovo. Chapter 7 provides the details on the design, methodology, and findings of this study.

Similarly, also in the second interview study, an interview guide was formulated based on TAM constructs (section 2.5), considering also a new variable, the truth-telling, which emerged from the findings of the first interview study. The triangulation process was used for confirmation and completeness of the findings presented from both interview studies (as discussed in section 8.2).

3.6 Conclusions

This chapter aimed to present an overview of the research approaches and their corresponding details to facilitate the decision on the research instrument for this thesis. Furthermore, besides the approach to the research, other processes should be considered before starting with the data collection. Hence, as discussed in this chapter, the research ethics, research trustworthiness, and related techniques for ensuring it, present important procedures that a researcher should consider and design carefully.

Hence, considering the aims and objectives (section 1.5), the critical analyses of the existing studies (sections 2.4 and 2.6), and the emerging research questions (subsection 2.8.3), this study concluded that there was a need to investigate users' adoption of sensor-based platforms, taking into account the lack of application of such platforms for remote and continuous patient monitoring in Kosovo. Furthermore, there was a lack of evidence on sensor-based applications' acceptance and healthcare professionals' readiness to use such platforms and provide feedback to remote chronically ill patients, in a SEE developing country, and Kosovo. All these lead towards a qualitative method for both empirical studies as elaborated in section 3.5.

The next chapter (4), presents the design details of both interview studies conducted in this thesis. This chapter summarizes the details that were common for the first and the second interview study with healthcare professionals such as the ethical approval process, setting where the interviews were conducted, recruiting details, and sampling approaches.

Chapter 4 Design of the interview studies

4.1 Introduction

As discussed in chapter 3, the research methodology should be planned thoroughly, organized accordingly and the researcher needs to make important decisions during the design process. This includes the decision on the setting where to perform the study, the recruitment procedure, data collection, and data analysis. As Flick (2007) suggested these processes should suit the study aims to provide understandable results and address the research gaps. Hence, this chapter will present detailed information on the design of the empirical studies performed in this thesis. As presented earlier in section 3.5, this thesis used two qualitative interview studies to investigate the adoption, acceptance, and implementation of sensor-based platforms for remote and continuous monitoring of chronically ill patients in a developing country, Kosovo. In this way, this chapter will elaborate on the procedures that were followed during the design of both interview studies, following the guidelines and policies of the University of Sheffield (2021). There will be specific details that differ from interview study 1 (chapter 5) with the interview study 2 (chapter 7), and those as included in their respective chapters.

This chapter is organized to present the importance of design on qualitative research in section 4.2. The details on the research ethics process that this thesis followed are elaborated in section 4.3. The information on the setting of this study, the American Hospital in Kosovo, is presented in section 4.4. A detailed design and corresponding information on data collection instrument, participants, recruitment procedure, the forms designed for use during the interview studies, data analysis, and piloting processes, are presented in section 4.5. Section 4.6 concludes this chapter.

4.2 Design of qualitative research

In the previous section 3.2, various approaches to undertaking a qualitative study were discussed. The selection of an appropriate qualitative approach mainly depends on the research questions and the phenomena under investigation. As Hancock, Ockleford, and Windridge (2007) mentioned, those different approaches provide different views of the same phenomenon. In this way, the path for the appropriate decision regarding the methodology is to first design the process.

The research design presents a process whereby the researcher states step-by-step the procedures, methods, instruments, or components that the study is going to adopt. Hence, Figure 4.1 shows the research progress for this study that includes the design graph adapted from Flick (2007) which was suited to this thesis.

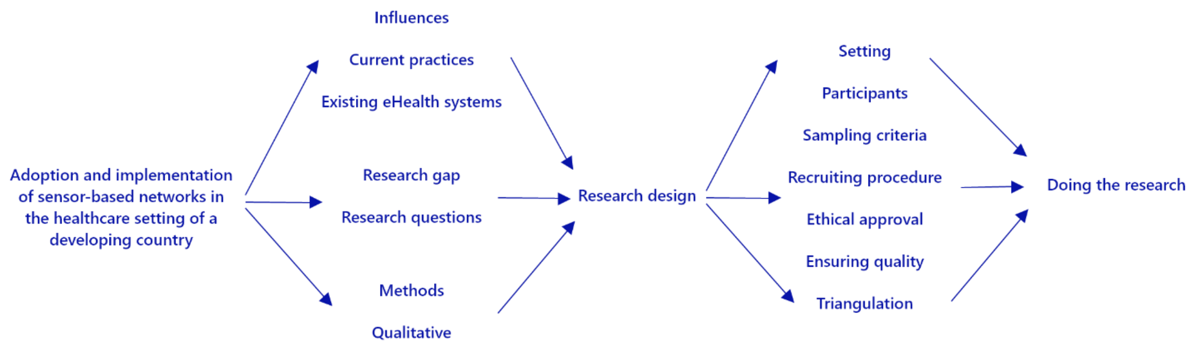


Figure 4.1 Research progress for this thesis, including the research design (adapted from Flick (2007))

As presented in Figure 4.1 and also according to Cassell and Symon (2004), the following steps should be considered during the design of the qualitative research process:

- Defining the research questions

  This is the primary step before continuing with the research and methodologies. The research questions for this thesis were presented in subsection 2.8.3, following the literature review.
- Creating the interview guide

  The interview guide includes a set of questions that the interviewer will discuss with the interviewee. The interviewer should try to cover most of the areas identified in the interview guide. Possible sources for topics that may be included in the interview guide are usually formulated from the literature review, study aims, researchers' interests, and experience in the specific research area. The interview guides may use probes that depend on the interviewee's responses. An example of an interview guide is presented in Table 4.1.
- Selecting participants

  This process includes the selection of a group of participants which represents another bigger group (population). The process of selecting the interviewees, determining their number, and related issues are closely related to the sampling strategy which will be discussed in the next subsections (4.5.2 and 4.5.3).
- Continuing with the qualitative process

  After the design process, the researcher may continue with the interview process. Hence, having ready the interview guide, and after selecting the appropriate methods, as well as possible participants; the researcher may continue to gather data and after that to analyse and present them.

Table 4.1 Example of an interview guide

Main issues
1. How would you describe your knowledge of remote monitoring technologies, more specifically sensor-based platforms? Probe: Where did you hear for sensor networks? 2. What do you think of the currently offered services and equipment of the clinical centre? Probe: Are the staff supportive? 3. Which may be potential challenges from the patient's point of view? Probe: Why?

Questions for each participant

4. Could you please let us know about your experience with sensor-based devices (monitoring devices)?
5. What may be a reason for not using sensor-based applications?

Nevertheless, as discussed in the previous section 3.3, for a research study it is important to consider the guidelines and compliance with the ethical issues and approvals of the institutions where the research is performed or supported, before starting with the data collection process. Hence, the next section provides details on the ethical approval process that was followed for both interview studies conducted in this thesis.

4.3 Ethical approvals

The research approach for this thesis consisted of an investigation with human participants, more specifically healthcare professionals who monitor chronically ill patients or related chronic conditions. Therefore, the research with human interviewees most of the time requires ethical approval (Schroter et al., 2006) which needs to be defined and get approved by the research ethics boards.

This thesis followed the guidelines and policies of the Research Ethics Committee within the University of Sheffield (University of Sheffield, 2021) and the Ethical Committee of the American Hospital, which was the setting of this research study. As such, this study went through the ethical process two times during the periods September – October 2016 and April - July 2020 (for two interview studies) in two different organisations, at the University of Sheffield and the Ethical Committee of the American Hospital. The procedures for ethical approval for both interview studies were very similar and they are presented in the following subsections.

4.3.1 Ethical approval for the first interview study

In compliance with the guidelines of the University of Sheffield (2021), an online application was filled out and submitted in the Ethics Application System offered by the University, as presented in Appendix A.1 of this thesis. All the corresponding information and the required forms during the interviewing process were submitted together with this application. Hence, there were included the Information Sheet (Appendix A.5), Consent Form (Appendix A.6), Demographic Questionnaire (Appendix A.7), and Interview Guide (Appendix A.8). A copy of the approval letter from the Research Ethics Committee within the University of Sheffield is attached in Appendix A.2, in this thesis.

A similar procedure was followed also for requesting the ethics approval from the investigation setting, back then, the UCCK. Nevertheless, despite several requests and physical meetings with the corresponding director of the Research Ethics Committee within the UCCK, this study did not get any reply or approval from them. Hence, not to delay further the research process, another investigation clinic (the American Hospital of Kosovo) was selected and the research ethics request was approved by them. The management of the hospital was informed by the director and the corresponding interviewing forms were translated into Albanian, as the native language of the participants, and were physically submitted to them during the ethical approval process. A copy of the approval letter is attached in Appendix A.3, in this thesis.

Following the non-responsiveness of the first institution (the UCCK), and the ethical approval of the second healthcare centre (the American Hospital in Kosovo), the author of this study informed the Research Support Manager in the Information School at the University of Sheffield in writing about the change to the location of the study. An email confirmation following this change was approved and is attached in Appendix A.4 of this thesis.

4.3.2 Ethical approval for the second interview study

The research ethics approval for the second interview study followed quite a similar procedure as the previous one, presented in subsection 4.3.1. Again, this study discussed with the American Hospital in Kosovo to interview the same healthcare professionals who participated in the first interview study. In this meeting with the director of the hospital, the corresponding information was given and the study purpose was discussed. Hence, the research forms before the ethical approval were provided to the director and after a thorough discussion with the board of the hospital, this study was granted the ethical approval to perform another investigation. The corresponding forms that were provided during this phase of research were: Information Sheet (Appendix B.4), Consent Form (Appendix B.5), Demographic Questionnaire (Appendix B.6), Interview Guide (Appendix B.7), and the List of tasks that the participants needed to perform with the proposed sensor-based prototype (Appendix B.8). All these forms were also translated into the Albanian language, as the native language of the participants. A copy of the approval letter from the American Hospital in Kosovo for performing the second interview study is attached in Appendix B.3, in this thesis.

The same documents were attached to the ethics application submitted in the Ethics Application System of the University of Sheffield, as presented in Appendix B.1 of this thesis. Considering that the second interview study was conducted during the Covid-19 pandemic situation (years 2020-2021), there was more information required (fields with information to provide in the system) while applying for the ethical approval, which was provided to the University to ensure participant's and researcher's wellbeing. A copy of the approval letter from the Research Ethics Committee within the University of Sheffield for performing the second interview study is attached in Appendix B.2, in this thesis.

4.4 Setting

The research in this study was conducted in one of the largest private hospitals in Prishtina[5], the American Hospital of Kosovo (2021). This hospital is registered as a general hospital as it consists of departments such as Allergology, Anaesthesiology, Check-Up, 24-hour Emergency service, Endocrinology, Gastrohepatology, Gynaecology Obstetric, Hematology, Infectology, Cardiovascular Surgery, Cardiology, General Surgery, Plastic Surgery, Laboratory, Family Medicine, Neurology, Oncology, Orthopedics, Neonatology, Pediatrics, Pulmonology, Radiology, and Advanced Imagery, Reanimation and Intensive Care, Rheumatology and Urology. This hospital setting was chosen because it had a range of departments that were likely to treat patients with a range of chronic illnesses.

The focus in this study was on departments in the hospital where patients with chronic illnesses were being treated or monitored continuously, i.e., the Cardiology department (consisting of two wards, 12

[5] Capital city of Kosovo

beds), Ambulatory-Cardiology department (6 beds), Intensive department (12 beds) and General Surgery department (12 beds).

4.5 Methods

This section provides information on the methods used for investigating healthcare professionals' perceptions and usage of sensor-based platforms for remote and continuous monitoring of chronic diseases, to ensure patient care in Kosovo.

4.5.1 Data collection

In qualitative research studies, there are various data collection methods, as discussed earlier in subsection 3.2.1.2. Considering the emerging research questions, and the lack of previous research on the adoption and implementation of sensor-based platforms for remote and continuous monitoring of patients, in Kosovo, or a SEE developing country, this thesis decided (section 3.5) to use interviews as a tool for exploring healthcare professionals' perceptions, opinions, and get their feedback on the investigated phenomena. Furthermore, the interviews were the most commonly used method for data gathering in qualitative studies (Cassell & Symon, 2004).

Similar studies (Davis, M.M. et al, 2014; Steele et al., 2009) during their investigations on remote monitoring technologies and peoples' attitudes towards their usage, have combined semi-structured and in-depth interviews (details were presented in subsection 3.2.1.2). This approach provided the interviewees the freedom to express their opinions on the specific topic and provide information on the research questions set at the beginning. Therefore, this approach seemed appropriate and feasible also for this thesis, considering that an Interview Guide (i.e., Appendix A.8) was already prepared and it enabled the participant to discuss freely beyond the predefined questions there. Through this approach, this thesis aimed to elaborate with the interviewees on a set of predefined questions, and also provide the possibility to further deepen the discussion on other topics that may be interesting to be explored.

Interviews are usually recorded so that not to lose track of the information (Flick, 2007). Hence, Britten (1995) also discussed that taking notes before or after the interview may not be appropriate. Therefore, recording and transcribing the interview was considered helpful and a method used in other similar studies in the literature (Chianga et al., 2015; Davis, M.M. et al., 2014; Steele et al., 2009; Tunlind et al., 2015; Yang et al., 2015). An example of a transcription box is presented in Table 4.2.

Table 4.2 Example of a transcription box

Transcription example
I: Could you please let us know about your experience with sensor-based devices? HCP: I do not have any experience, actually it is the first time that I hear from them …. after explaining the application of SBNs, and describing the concept I: What do you see as a potential benefit of using sensor applications in healthcare? HCP: They look very interesting (2s) and seem to be helpful, but I am not sure [in doubt] if they can be applied in this clinical centre.
I = Interviewer, HCP = Healthcare professional

As seen in Table 4.2, the recorded interview is transcribed into textual information, including all the details about the pauses, tone, and participant. Hence, after the design of the data collection method, a researcher should think of the recruitment procedure, or how to approach participants and start the investigation. These details are discussed in the following subsection.

4.5.2 Participants

In qualitative approaches, there is not a strict line that determines neither who to investigate nor the number of participants. These depend on the purpose of the research, the depth of the interview, research aims, and questions. Hence, for this thesis, the eligibility criteria were that participants had to be healthcare professionals, nurses, and doctors, who were treating patients with a chronic disease or were monitoring chronic parameters, such as vital signs. A specific range of age limits, academic qualifications, years of work experience, or department that they were working, was not set. The aim was to include as many participants possible considering the number of available staff in the setting (section 4.4). As such, this study included participants of different age groups, academic qualifications, and work experiences, these are presented in subsection 5.5.1 and subsection 7.5.1.

Considering the context of this study, the American Hospital of Kosovo (section 4.4), the group of participants consisted of medical emergency teams (nurses and doctors who worked in the Ambulatory Cardiology Unit), critical care teams (nurses, doctors, and anaesthesiologists who worked in the Intensive Care Unit), and general doctors who work in the Cardiology Unit.

4.5.3 Recruitment procedure

Considering this study's research aims and questions, and the existing sampling strategies as discussed in subsection 3.2.1.3, this thesis had a predefined approach that led to purposive sampling. Hence, the emerging research questions and the need for research in a developing country, Kosovo (section 1.4), suggested recruiting healthcare professionals that monitored patients with chronic conditions. As this research study was conducted in a private clinic, the number of participants was not high, and no further criteria were necessary. Furthermore, as many profiles and working backgrounds were involved in this study, the richer was the information gathered, considering that no previous research was conducted in this regard.

Besides the purposive sampling, this thesis combined also other sampling strategies, for example, convenience sampling, and snowball sampling. The convenience sampling was appropriate considering that the interviews were conducted on hospital premises and during the working schedule of healthcare professionals. Hence, it was important to access available participants. The snowball sampling was used in cases when a participant proposed another colleague that participated and contributed with his/her experience in the study.

4.5.4 Forms used during the interviewing processes

Before the interviewing process, there were a set of documents and forms that were presented to every interviewee to provide details on the study purpose and inform the participant about the data anonymity, the interviewing procedure, withdrawal from the study, recording of the interview, transcription for research purposes, and how the data would be used after the analysis process. The following subsections will provide design considerations while formulating these forms.

4.5.4.1 Interview guide

The interview questions were summarized in a document used by the researcher to guide during the interviewing process. The questions included in the interview guides (Appendix A.8 and B.7) were formulated based on the study aims and with the purpose of generating information to answer the research questions (subsection 2.8.3) of this thesis. Furthermore, various technology acceptance variables (section 2.5) were used for understanding better the different aspects of healthcare professionals' acceptance and adoption of sensor-based platforms.

The questions in the interview guide were designed carefully in order not to be misleading, misunderstood, and complicated to answer. Hence, as suggested also by Cassell and Symon (2004), both interview guides (first and second interview study) started with a general question or one that the interviewee could answer easily. Moreover, the interview questions followed a logical order to provide meaningful answers and information. At the end of each interview, the researcher closed by asking the participant about the interviewing experience, or if there were further comments that were not discussed during the interview.

The interview questions were formulated by avoiding multiple answers to the same question, for example, how can sensor applications help the treatment and management of chronic diseases, and do you think that you would use them? In these cases, the interviewee will tend to answer once and this may lead to a response on a single question. Also, leading questions were not included in the interview guides for this study. These types of questions limit users from expressing their opinions, for example, so you think that sensor networks will enhance health delivery, do you? Hence, this thesis tried to avoid these types of questions and include those that would trigger the participant to talk more and provide information on the investigated phenomena.

4.5.4.2 Consent form

The consent forms for both interview studies were designed following the guidelines and principles of the University of Sheffield (2021). Hence, for the interview studies that involve human participants, it was important to get their consent on voluntary participation in the study, to provide information on the recording procedure of the interview, and how the data provided will be used for future research.

The consent forms of this thesis (Appendix A.6 and B.5) were prepared to be filled out by the participant and have their signatures at the end of each form, considering that the interviews were conducted physically. Consequently, before starting the interviewing process, each participant was informed about the study purpose. After that, if they were willing to participate, the consent form was read and signed by them and by the researcher. Two copies were provided, one for the participant and one for the researcher.

4.5.4.3 Demographic questionnaire

This research study used demographic questionnaires to understand the profiles of the participants and their experience with digital technologies and remote monitoring. These questionnaires did not include any personal information that could reveal a participant's identity. Hence, the questions were related to their gender, age, working profile, years of professional experience, and familiarity with digital technologies.

There were designed two different demographic questionnaires that suited the aims of the first and second interview studies, as presented in Appendix A.7 and B.6.

4.5.4.4 Tasks performed with the proposed sensor-based prototype

During the second interview study, a separate document was provided to participants and it included a list of tasks that they needed to perform with the proposed sensor-based prototype. This document was formulated following the functionalities of the proposed SBNHealth prototype, and to help the healthcare professionals navigate easily through the system to provide their feedback afterward. This document is attached in Appendix B.8.

For qualitative research, it is also important to design the process of transcribing and analysing the collected data. Hence, the following subsection provides details on the data transcription and analysis process followed for both interview studies in this thesis.

4.5.5 Transcription procedure

Interviews for both research studies in this thesis were recorded in the Albanian language as a native language spoken in Kosovo. These recordings were primarily transcribed in Albanian in separate files which then were translated into English. The collected data were stored and analysed anonymously using a keyword and a number, for example, *Interview 1, nurse*.

While transcribing the interviews, there were cases that healthcare professionals were not so clear, therefore further explanations were included in brackets to explain the situation. This was obvious as the researcher understood the context of the conversation, the body gestures, the tone of the voice, and similar expressions, that were not so evident from the recordings. Furthermore, dots in the transcription files were used to present participants' pauses, for example, one dot means a second of pause, two dots mean two seconds of pause, and similar. If participants' pauses were longer, i.e., more than three seconds, they were presented with brackets and numbers, for example: (5s) for a five-second pause.

4.5.6 Data analysis

Throughout the two data analysis processes for both interview studies conducted in this thesis, thematic analysis (subsection 3.2.1.4) was applied to provide meaning and an understanding to the gathered information (Braun & Clark, 2013). Hence, the six stages of thematic data analysis were followed.

The interview data generated from the interviews were primarily transcribed into Albanian as this was the language that the interviews were conducted. This helped the researcher get familiar with the data and was seen as the first phase of the data analysis process (Phase 1: Familiarization). The benefit of the first stage was that the researcher was involved in the data collection process and in this way had a good understanding of the data and the gathered information. After transcribing, the researcher translated all the data into English. In this way, the researcher developed some thoughts about the data and got very familiar with them.

Translated transcriptions were imported into NVivo which facilitated the process of generating codes (Phase 2: Generation of codes). Initial codes were generated automatically from NVivo; however, they were refined from subsequent readings of the interview transcripts. Hence, having coded the interview data it was easier to generate themes that consist in the third phase of the qualitative data analysis process (Phase 3: Identification of themes).

The fourth stage of the thematic data analysis, was related to the verification of the themes. During this phase, it was decided that some candidate themes were not really themes, for example, there was not enough information to support them, or the provided information was too diverse, or some other proposed themes could collapse into each other (Phase 4: Verification of themes). Hence, the fifth stage of thematic data analysis, the collating and refining, helped to set up and shape the context of each theme that was derived from the data analysis process. This process included detailed information on each theme and determined which aspects of the information they captured, for example, the sub-themes (Phase 5: Defining and naming themes). Finally, the last stage of thematic data analysis was related to the generation of data sets and writing up all the information that emerged from this process (Phase 6: Producing the report). In this way, these six phases simplified the data analysis process and enabled a detailed evaluation of the findings to be generated from the interview studies.

4.5.7 Piloting

Qualitative research is a process that does not define a strict line for starting and ending the investigation. Thus, it does not suggest a secure path that will lead the researcher to understand and solve the problems related to the phenomena under investigation. As such, the qualitative approach highly depends on the study aims and the research questions, and it cannot generalize all possible research cases. Therefore, Cassell and Symon (2004) suggest that the researcher should test its design in a smaller group of people and then apply it to a larger sample. This procedure is performed through a pilot study.

Piloting in this thesis was applied to a small group of participants to test and evaluate the methods, the research instrument, and the predefined interview questions. These are described further in sections 5.4 and 7.4. Therefore, the piloting helped to assess the already defined interview schedule, forms, clearness of the investigation and improved the communication between the interviewer and the interviewee. The results of the pilot study were used to further enhance the interviewing materials, including questions, forms, and the overall research instrument. Therefore, in both interview guides (Appendix A.8 and B.7) there is a set of questions related to the interviewing process and interview questions, that were asked to a small group of participants at the beginning of the interviewing process. The piloting phase for the second interview study, as presented in subsection 7.4, was performed after implementing the SBNHealth prototype, which was developed based on the findings of the first interview study.

4.6 Conclusions

This chapter provides an overview and summary of the design of the interviewing process applied in both empirical studies of this thesis. Hence, it presented the key points and procedures applied for understanding healthcare professionals’ attitudes and adoption of sensor-based platforms (chapter 5), and evaluating the proposed sensor-based prototype (chapter 7).

As this thesis consisted of two interview studies, very similar ethical procedures were followed in both cases. This applied also to the interviewing forms, data collection method, participants, data analysis, and piloting. Nevertheless, some details differ the process of the design between the first and the second interview study. These details are elaborated in the respective chapters of these interview studies.

Hence, considering the overview on the design of the interview studies, the following chapter (chapter 5) presents the first investigation with healthcare professionals to understand their views, opinions, and perceptions on using sensor-based platforms for remote and continuous monitoring of chronically ill patients in Kosovo.

Chapter 5 Healthcare professionals’ attitudes and perceptions, First Interview Study

5.1 Introduction

The literature search and in-depth review of the existing studies in chapter 2 showed that there was no previous work published on the sensor-based acceptance and adoption in any developing SEE country, and not in Kosovo. Hence, it was considered important to understand and investigate the healthcare professionals’ perceptions towards eHealth applications based on sensors, to facilitate and further improve the digitalised healthcare services in developing countries, and encourage the use of remote and continuous monitoring technologies for chronically ill patients.

Consequently, the study presented in this chapter aimed to investigate the adoption, acceptance, and usage of sensor-based platforms for remote and continuous monitoring of patients, in a developing country, Kosovo. Hence, the data analysis and overall findings of this research work presented in this chapter set a specific list of requirements and details for consideration from the system designers before proposing sensor-based platforms for healthcare settings. In this way, section 5.2 presents more details about the aims and research questions of the first interview study with healthcare professionals. Methods used to address these research questions are elaborated in section 5.3. Section 5.4 presents details on the pilot study conducted before the main interview study. The findings of this interview study are elaborated through themes and their underlying sub-themes in section 5.5 and its corresponding subsections. A model-driven discussion of the overall results of this interview study is presented in section 5.6. The strength and limitations of this interview study are included in section 5.7. Finally, section 5.8 concludes this chapter by providing the research questions' outcomes and the key findings in separate subsections.

5.2 Aim and research questions

This qualitative study aimed to investigate healthcare professionals’ perceptions and attitudes towards the application of sensor-based platforms for continuous and remote monitoring of their chronically ill patients. The questions that this stage of the research aimed to answer, and are aligned with the overall research questions of this thesis presented in subsection 2.8.3, were as follows:

1. In what context, will the application of sensor-based platforms help developing countries, in this study Kosovo, to treat and manage chronic diseases?
2. What may be the factors that can challenge the implementation of SBN in the health system of Kosovo?
3. What are possible recommendations for a successful implementation of an SBN architecture in a developing country such as Kosovo?
4. How will the application of sensor-based networks affect healthcare professionals’ work and patient care?

To answer these research questions, this study designed methods for interviewing healthcare professionals as described in the next sections.

5.3 Methods

This section provides details on the methods used for investigating HCPs' acceptance and adoption of sensor-based platforms for remote and continuous monitoring of their chronically ill patients. As elaborated in chapter 4, this study used semi-structured and in-depth interviews to understand HCPs' perceptions and their experience with sensor-based platforms in Kosovo. Hence, this section provides specific details on the design of this interview study, recruitment, and interviewing process, that differ from the general details presented in chapter 4.

5.3.1 Design of this interview study

The design of this interview study followed a similar flow of processes as presented in chapter 4. Hence, it started with the creation of the forms that were used during the interviewing process, such as the Ethics Application (Appendix A.1), Information Sheet (Appendix A.5), Consent Form (Appendix A.6), Demographic Questionnaire (Appendix A.7) and the Interview Guide (A.8). The formulation of these forms was based on the guidelines and policies of the University of Sheffield, the study aims and research questions (section 5.2), and the ideas included also in other similar studies. Specific details on the creation of the forms used during both interview studies were elaborated in subsection 4.5.4. Furthermore, the interview guide included questions formulated based on various technology acceptance concepts, and this helped to discuss the findings of this study according to them as presented in section 5.7.

This interview study was conducted in the American Hospital in Kosovo, a private hospital that consists of various departments that deal with many diseases (section 4.4). This study aimed to investigate healthcare professionals working with chronic diseases, or professional doctors, nurses, and physicians working either full time or part-time in the private healthcare sector. Nevertheless, some of the participants were also working in the public healthcare centre, the UCCK. The combination of work profiles, for example, five doctors were working in the public hospital as full-time cardiologists and in a private hospital as part-time cardiologists, enabled a wider range of data coming from both sectors of healthcare provision in Kosovo.

5.3.2 Recruitment

After getting the ethical approval from the two institutions (the University of Sheffield and the American Hospital of Kosovo) (subsection 4.3.1) an email was sent to possible participants who met the sampling criteria (subsection 4.5.2), as presented in Appendix A.9. Nevertheless, only a few of them confirmed their participation in the study through emails; as they explained, due to their workload, they could not reply. Hence, the management of the hospital proposed the administrative nurse as a contact person to arrange appointments with nurses who were willing to participate in the study. The doctors, however, were all contacted directly to avoid delays.

The recruiting procedure was initially planned and implemented as a purposeful sample; however, as recruiting progressed, it was necessary to adopt convenience and snowball sampling (subsection

4.5.3) to achieve a higher number of interviews. Purposive sampling was therefore initially used to ensure that healthcare professionals that deal with chronic diseases were interviewed. Convenience sampling is related to easily accessible staff members (Punch, 2014) and was also used in this study. Hence, the administrative nurse suggested other possible nurses who might be willing to participate. Snowball sampling was also used in two cases where a participant (doctor) suggested a nurse and a doctor that helped with their opinions in the study.

5.3.3 Interviewing process

The data collection process began on the 02nd of December 2016 and ended on 11th February 2017. During this time, 26 interviews were conducted and transcribed in Albanian and then translated into English. Each participant was given an Information Sheet and was explained in detail the idea of the study. If the participant agreed to participate in the interviewing process, then the consent form was signed. All the interviews were recorded only for transcription purposes. Before the interviews, participants filled a demographic questionnaire that did not reveal their identity.

As shown in Table 5.1, this qualitative study consisted of 866 minutes and 35 seconds of recording. The length of each interview was measured from the first interview question until response was concluded to the final question. Hence, this time represents a valid interview recording time-length. When there were emergencies, the recording was paused, and it was continued afterwards.

There were 14 nurses and 12 doctors who were interviewed and recorded within the hospital premises. The interviews with doctors were recorded in the doctors' rooms, whereas interviews with nurses were recorded in the nurse's rooms or staff rooms. Participants' names were substituted with abbreviations and a number, for example, *Interview 1*. Table 5.1 presents a summary of the characteristics of the sample of this interview study, participants' profiles, and the length of the interview in minutes and seconds.

Table 5.1. The timeline of the interviews, and the profiles of the interviewees

Interview	Profile	Total length (mm: ss)
Interview 1	Nurse	54:23
Interview 2	Nurse	36:18
Interview 3	Doctor	21:43
Interview 4	Doctor	30:19
Interview 5	Nurse	43:27
Interview 6	Doctor	10:56
Interview 7	Doctor	22:16
Interview 8	Nurse	26:23
Interview 9	Nurse	33:38
Interview 10	Nurse	26:54
Interview 11	Doctor	31:17
Interview 12	Doctor	23:35

Interview 13	Nurse	21:43
Interview 14	Doctor	38:67
Interview 15	Doctor	36:35
Interview 16	Nurse	32:66
Interview 17	Nurse	49:06
Interview 18	Doctor	43:74
Interview 19	Nurse	32:02
Interview 20	Nurse	20:39
Interview 21	Nurse	30:35
Interview 22	Nurse	30:23
Interview 23	Nurse	32:54
Interview 24	Doctor	47:00
Interview 25	Doctor	44:37
Interview 26	Doctor	48:27
Total		866 minutes and 35 seconds
Mean		33 minutes and 30 seconds

The interviewing process can be described as time-consuming as it took place within the hospital premises. There were four cases that the interviews were paused and continued after emergencies. Some of the interviews were recorded based on the participants' shifts, for example, day shift and night shift. Moreover, two participants hesitated to have the interview recorded. However, after detailed information on the study aims and data anonymity, these participants agreed for the interview to get recorded for transcription and research purposes only.

5.4 Pilot Study

The pilot study aimed to test the appropriateness of the data collection tool and the prepared interview guide. Furthermore, its goal was to understand if the formulated questions were appropriate to provide useful information for answering the research questions.

The piloting phase included six interviews (three nurses and three doctors) from various departments, as follows: a nurse working in the Cardio-Surgery department, the head-nurse of the Cardiology department, an Anaesthesiologist, a Neurologist, a nurse working in the Ambulatory-Cardiology department, and a Cardiologist. These participants were informed about the aim of the study through the information sheets, they were given the possibility to ask questions and further explanations before the interviewing process, and after their confirmation to participate in the study, they were given the consent form which was signed from the interviewee and the researcher. A demographic questionnaire was filled out at the end of these procedures, before starting with the recording of the interviews.

5.4.1 Lessons learned from the pilot study

The pilot study enabled the researcher to get familiar with the research setting, various profiles of the participants, and the data collection instrument. Hence, the proposal to use semi-structured and in-depth interviews as designed in chapter 4, was supported and showed its benefits through this piloting phase. Therefore, it was clear that there are going to be additional questions based on the interviewee's answers which were further elaborated by using more in-depth investigation or arising questions based on provided answers.

The hospital where the interview study took place was using a digital monitoring system that enabled monitoring of heart rate through wired electrodes, oxygen saturation, pulse, and temperature. The digital system consisted of two types of screens (monitors) where one small screen was placed near a patient bed, and another big screen was placed near the nurses' central desk and was displaying all the views of small screens. In the display of these monitors were presented patients' vital signs, for example, the ECG with a graph, and values of pulse, oxygen saturation, and temperature. In case of irregular values, the system was providing an alarm through sound and light to inform the HCPs about possible deteriorations. Moreover, in the digital system, a monitoring staff could set the normal range of values for specific vital parameters based on a patient's condition. Considering this digital system, in the prepared interview guide, there were some questions regarding experience with digital technology. Therefore, there was evidence that the healthcare professionals had experience with digital technology, and these questions were refined and the focus was placed on remote monitoring that was based on sensor technology.

The pilot study confirmed the conclusions found in the literature regarding the challenges that qualitative studies imply, for example, some participants hesitated to get recorded. The idea of a private healthcare centre, was a bit complex as some participants were thinking that they were investigated from the hospital. However, after a brief conversation with them and the detailed information on the study aims, they were assured that it was just an investigation related to their opinions and attitudes towards the application of sensor-based platforms for remote monitoring of their chronically ill patients.

5.4.2 Conclusions of the pilot study

Piloting was a study based on a small sample size as the idea was to test the data collection tool and the predefined categories of questions (included in the interview guide, Appendix A.8) to understand if the research was covering the phenomena under investigation. This phase revealed that the combination of semi-structured and in-depth interviews was appropriate due to the various profiles of medical staff.

When investigating various clinics or departments, the researcher could see the different points of view and places where sensor-based technology could help the healthcare centre. Therefore, it was decided not to limit the sampling criteria only to cardiologists and nurses working in the Cardiology department. As presented earlier, part of the pilot study was also a Neurologist and an Anaesthesiologist who proposed very interesting and beneficial ideas of factors to consider while designing the sensor-based architecture and also other healthcare areas where the SBN could help them. All these details are presented in the next section.

5.5 Results

The data analysis process was briefly presented in subsection 4.5.6. Hence, as elaborated, the analysis of the interview studies performed in this thesis was based on the thematic data analysis process and used the six phases leading to the generation of themes and sub-themes, hence, indicating an inductive approach. Consequently, the following sections present the identified themes and their sub-themes for this interview study. The details on sample characteristics are presented in subsection 5.5.1. A brief overview of the findings of this interview study is elaborated in subsection 5.5.2. The rest of the subsections (5.5.3 – 5.5.8) present this study's findings categorized and presented through the main themes, which encapsulate findings on the sub-themes inside each corresponding subsection.

5.5.1 Sample characteristics

Once the data collection, transcription and translation processes were finished, gathered information was entered in two different software. The first part of the data analysis included demographic data that were generated from the questionnaires filled before the interviews (Appendix A.7). Statistical Package for the Social Science (SPSS) was used to code these data and analyse them. While the translated transcripts of the interviews were imported into NVivo to categorise and generalize the information in a more structured format.

Hence, this qualitative study included 26 interviewees, 16 females and 10 males. The majority of them (24/26) had a university degree. Details of the education level such as University degree, specialization and only medical high school are presented in Figure 5.1. The x-axis contains the education levels, University Degree, Specialization and Medical School; while the y-axis contains the number of participants. It is worth mentioning that there were participants that declared they have finished various training and attended international conferences too.

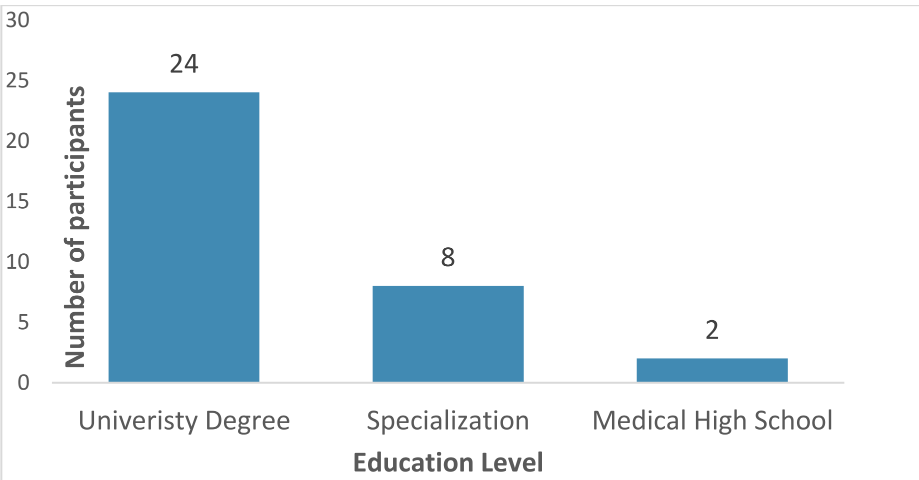


Figure 5.1. Education level of the interviewed healthcare professionals

Figure 5.2 presents participants' work experience, where as seen the majority of them, had more than 3 years of working experience in the corresponding healthcare sector.

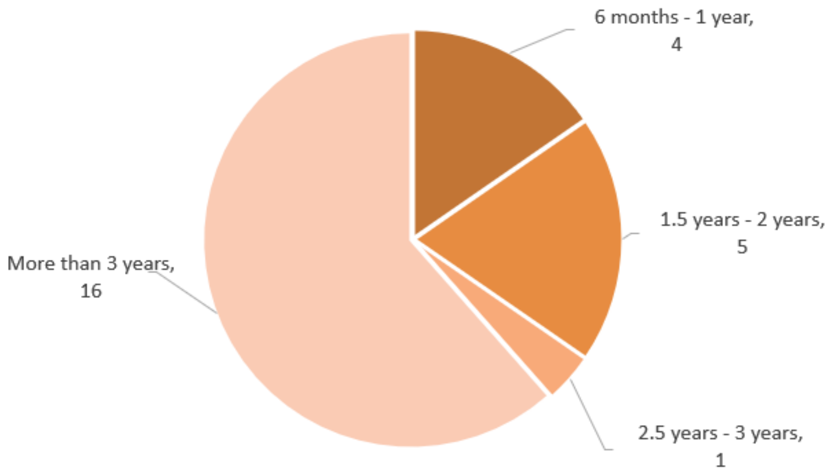


Figure 5.2. Frequency of length of work experience for the interviewees (n)

The interviews took place in a private healthcare centre, one of the biggest in Kosovo, however, six participants (out of 26) worked also in the public healthcare centre, the UCCK. This was considered helpful as the study included a mixture of work experiences in two institutions, which applied different technologies for monitoring their patients. The private clinic where this interview study was conducted (section 4.4) used a digital monitoring system for all its hospitalized patients, and some wired-based monitoring platforms for remote patients. While the public hospital, the UCKK, was mainly operating with old technologies and healthcare tools, as confirmed by the participants of this study.

The usage of digital technology was evident also from the results of the demographic questionnaire, where healthcare professionals confirmed the usage of it on daily basis. These results are summarized in Figure 5.3, where the y-axis presents four categories starting from those that did not use digital technologies for their work, then healthcare professionals that used desktops for their work, laptops or smart phones; while the x-axis shows the number of healthcare professionals.

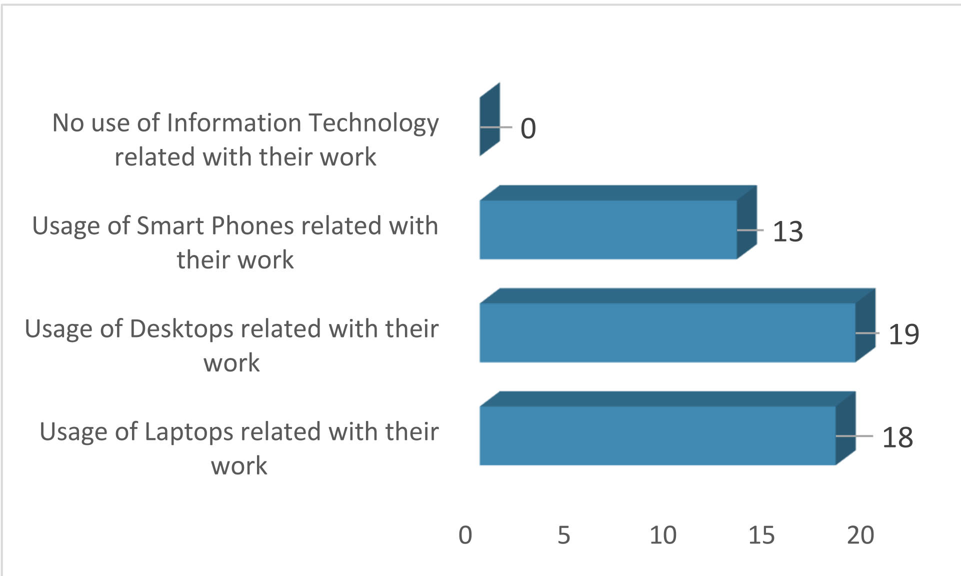


Figure 5.3. Usage of digital technology in healthcare professionals' daily work

Consequently, the education profile, work experience and usage of digital technology present some introductory information on the profile of participants for this interview study, which do not reveal their identity. Hence, the next subsection presents more information on the results of this interview study.

5.5.2 Findings of this interview study

While analysing gathered interview data, this study identified six main themes, as follows: the digital technology, the sensor-based networks, the wireless networks, the distance monitoring, the vital signs and a chronically ill patient's profile. Within each category of the identified themes, there are further sub-categories. These sub-categories were derived from participants' answers and the topics that they were talking about during this interview study. Hence, the complete graph of themes and their underlying sub-themes is presented in Figure 5.4.

The hospital where the interviews were conducted was applying digital technology, therefore participants were talking about the idea of digital technology, the adaptation process, advantages and disadvantages of information technology in healthcare. This led to the creation of the main theme, digital technology, as presented in Figure 5.4, and subsequent sub-themes. While discussing the application of remote monitoring platforms, some participants elaborated on the idea of wireless networks and their implications. Hence, the wireless network was included in the final graph of the themes for this study too. Further to these practices, this study aimed to understand the profile of chronically ill patients, i.e., their average age, living area, the number of visits that they had in the clinic, and similar information. The objective was to have an idea of the patients that needed remote monitoring, and how this could affect their care, provision of better healthcare services, and improve their life.

While discussing the chronically ill patients, this study investigated also the vital signs that were important to monitor. Hence, before proposing a sensor-based application, it was important to understand which vital signs the platform should monitor and provide information, the frequency of measuring them, the recording method, the data presentation, and the critical values based on healthcare professionals' current practices and methods.

After discussing most of the patient care aspects, this study investigated the overall attitudes towards distance-based monitoring, respectively the readiness to provide feedback to remote patients, the data that the healthcare professionals needed to provide reliable information to patients, and possible limitations of the remote and continuous monitoring for chronically ill patients.

Consequently, the above-mentioned topics present a roadmap towards the discussion on the application of sensor-based platforms for remote and continuous monitoring of chronically ill patients in a developing country, Kosovo. For this interview study, it was important to get participant's perceptions and attitudes on applying sensor-based platforms, on the benefits of these applications, possible implications into the healthcare settings including impact, drawbacks and challenges that a successful proposal of a sensor-based platform in a developing country such as Kosovo, may face.

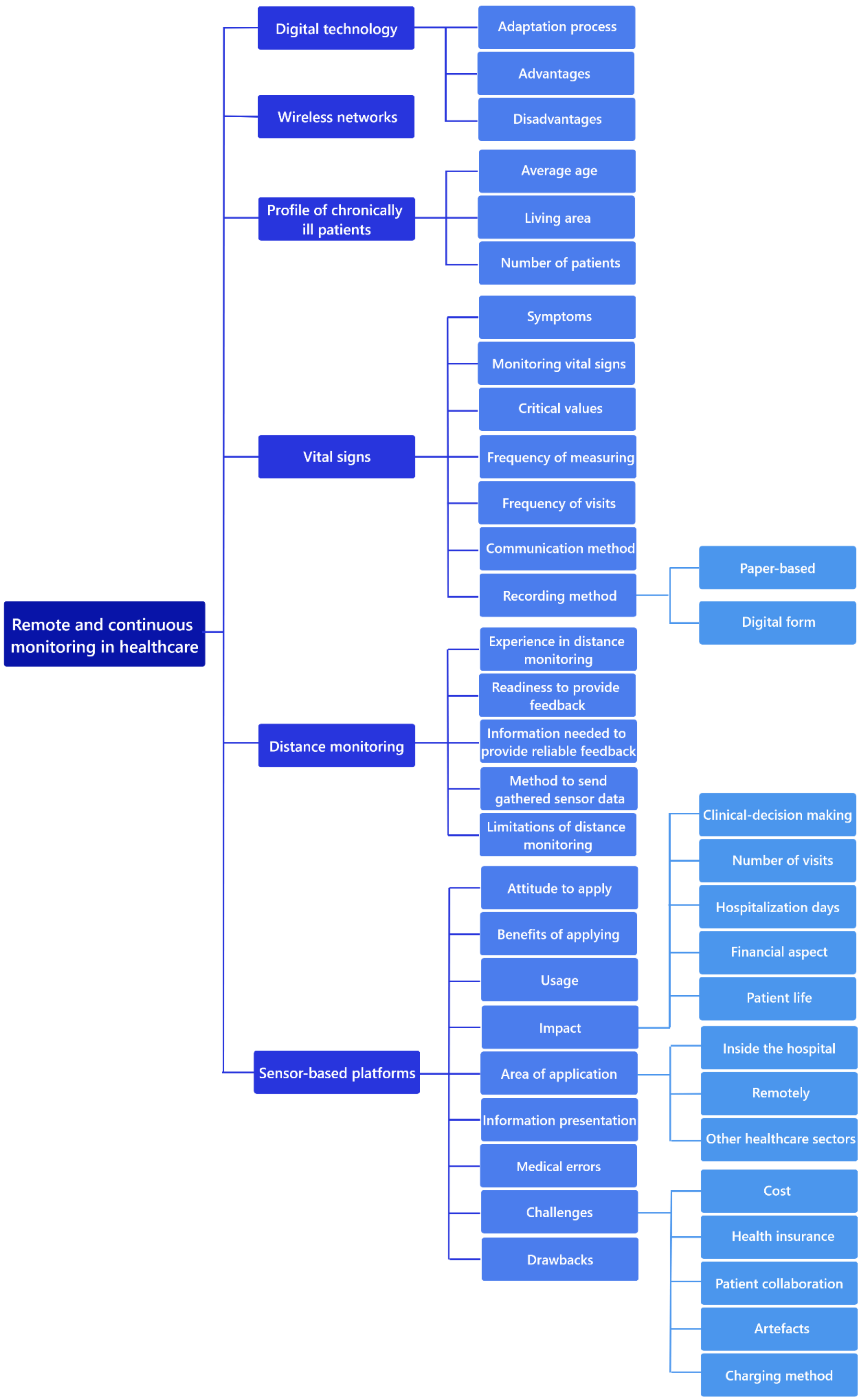


Figure 5.4 Themes and underlying sub-themes of this interview study

The following sub-sections will provide brief information related to each theme and its underlying sub-themes. After presenting all of them a discussion section will summarise the results gathered from collected interview data and will critically analyse them based on technology acceptance variables in section 5.6.

5.5.3 Digital technology in the healthcare centre

This subsection elaborates in detail gathered data from the interview study related to the usage of digital technology in the healthcare setting where the study was conducted. Here, the term digital technology refers to the digital monitoring system that the American Hospital was applying to continuously monitor hospitalized patients and record their data. The digital monitoring system consisted of:

> *"The ECG is placed on the shoulder and consists of special electrodes that are connected with the monitor. The cuff is used for measuring the blood pressure and it is placed in the arm, and pulse-oximeter is placed in the finger and is used to measure the oxygenation of the blood." (Interview 1. Nurse)*

> "A*bove patient's head is the monitor [screen] that shows the values of the blood pressure, oxygen saturation, respiratory frequency, ECG; in addition to this, there is also the central monitor [screen] at the nurses' desk, which displays all small parts of each monitor [screen] that is at the patient's head." (Interview 25. Doctor)*

> *"In the monitoring device, we set the normal range of values for specific vital parameters. And if the patient goes into fibrillation we are informed through an alarm, as the values are not within their normal range. The device displays a red mark. It gives an alarm.*" *(Interview 2. Nurse)*

The Holter monitors present another type of digital technology that was placed in chronically ill patients to monitor their heart activity and blood pressure at a distance. These devices were used to monitor patients for 24 or 48 hours continuously while the patient was outside the clinic. The patient brought back the device after it had recorded continuously his/her vital signs for the time set by the doctor. When the patient was returning the device, a nurse was connecting the Holter device with a computer and preparing the ECG graph or blood pressure values for the doctor to read them. Regarding Holter monitors, healthcare professionals said that:

> *"The device is small. They are of various suppliers. And once downloaded, the second day or it depends on how much it is kept [for how long the patient wears it], as recommended by a doctor; it has all the recorded data in it and we can have a pdf of all the data inside." (Interview 14. Doctor)*

The healthcare professionals do rely on the existing digital systems that they are using in different departments of the hospital, therefore they discussed in detail various aspects of the advantages, disadvantages, and the adaption process related to the application of these platforms, as presented in Figure 5.5.

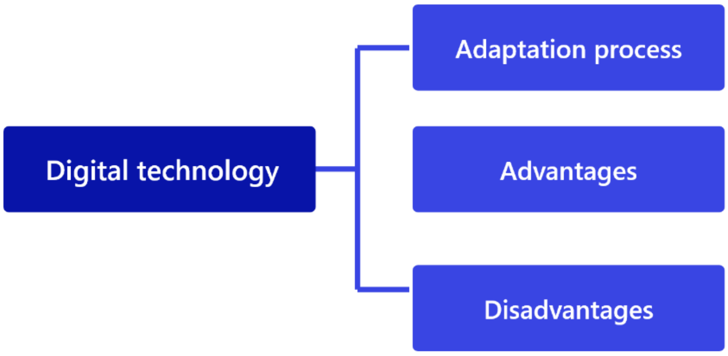


Figure 5.5 Sub-themes of the digital technology

The sub-themes of the digital technology theme, as presented in Figure 5.5, emerged from the gathered interview data. Hence, the following subsections provide more details on each of them.

5.5.3.1 Adaptation process

Participants of this interview study had training before using the digital monitoring systems presented in the previous section, from the providers of the system. Hence, the provided training facilitated the adaptation process of the digital systems, for example:

> "W*e had training before we started working with this system. We had [training] with Germans, which were representatives of Drager [manufacturer of the monitoring system].. I have been in training just for three days since there are not too many things." (Interview 8. Nurse)*

> *"It was not difficult. It was easy. Of course, while they get printed [the patient reports] someone told us, instructed us, and we have learned it very well." (Interview 21. Nurse)*

In the organizational aspect considering that the American Hospital of Kosovo was a private healthcare centre, participants were somehow obligated to use the system and work with it. From the individual perspective, on the other hand, they seemed to like the system and have adapted it quickly and it did not seem that age was a problem to use these platforms, as these doctors also mentioned:

> *"Well compared to what I have experience, when we worked without the monitor, then the monitors [refer to the digital monitoring system].. this here is very advanced technology. So, it is a great relief to work with them every day." (Interview 3. Doctor, age 55-64[6])*

> *"It was nothing. That screen is a screen [refer to the digital monitoring system]. You select the button to measure the blood pressure and blow out the cuff and it displays in the screen." (Interview 7. Doctor, age 35-44[6] above)*

> *"I work for the past five years here in the hospital and (.) not a problem but only that it seemed much easier. A good thing." (Interview 10. Nurse, age 25-34[6])*

[6] Age is placed here just to demonstrate that this was not a factor that has influenced the adaptation process of digital technology.

These examples indicate that healthcare professionals of mid-and-older ages think that the adaptation process of the digital monitoring system was not complicated, so does its usage. This is further elaborated through the advantages that these participants mentioned, as presented in the next subsection.

5.5.3.2 Advantages

The healthcare professionals during this interview study mentioned several advantages that digital technology offered to them. They mentioned how the digital monitoring system has facilitated their work by continuous monitoring, or by providing a 24 hours report on the patient's condition, or by providing alarms when the patient was not fine. In this way, medical personnel thought that their work became easier with the application of the digital monitoring systems as well as the assistance provided was quicker, as suggested:

> "*Compared to the traditional methods, measuring with cuff, putting the stethoscope, checking whether you are listening well; now we have the digital monitoring system that we can assign to measure the vital signs every 5 min, every 10 min, every 15 min, and it just shows us the results and we monitor the patient.*" *(Interview 16. Nurse)*

> "*It has facilitated our work for 80%. Because the patient is monitored all the time. It happens many times that you have things to do and the condition of the patients in Cardiology can worsen in two-three seconds, so for example, while you are giving the other [patient] perhaps a glass of water or helping something, another patient has already worsened and the alarm indicates this in a second, and you give priority to him/her. Our job is easier and we can assist quickly. The possibility for the patient to survive and pass the risk is higher. "(Interview 2. Nurse)*

Furthermore, continuous and remote monitoring has its benefits too, as discussed by a doctor taking as an example the Holter monitoring or pacemakers that they apply in remote patients, as follows:

> *"I put a Holter to see if there is a pause. If the rhythm slows down so much that can give any significant pause, for example, those 2-3-second pauses are important. There have been times when I have put the Holter to a patient, on the first day noting serious was registered, on the second day it recorded a pause of almost 11 seconds (..) that justified then the placement of a pacemaker." (Interview 7. Doctor)*

Similarly, Guo et al. (2021) concluded that the application of digital technologies can help to detect critical conditions that affect a patient's well-being. This was further elaborated by the participants in this interview study, for example:

> "*I would say it is a relief for the patient. He/she puts it, makes the life normally [referring to the placement of Holter].*" *(Interview 13. Nurse)*

> "*They feel safe enough, secure... because he/she can see that is being monitored. It is absolutely a safety feeling for the patient.*" *(Interview 3. Doctor)*

> *"Easier, for us and the patient. Because for example, the patient is with a chronic disease and if you go every 10 minutes or every 15 minutes and remove the cuff, put the cuff again..*

whereas here [in the digital monitoring system] you just put it and press the button and it measures itself." (Interview 10. Nurse)

Considering the above examples, it is noticed that nurses used the digital monitoring system and after that, they informed the doctors. The possibility of having alarms made them feel more comfortable as they knew they would receive an alarm in cases of irregular values of vital signs. Hence, they could set a range of normal values for the patient, and when the vital parameters were not within the specified range, the digital monitoring system was providing an alarm, as explained:

"Y*ou are somehow more relaxed because you know that if something goes wrong you have an alarm." (Interview 2. Nurse)*

"Here we have the alarms if the values... if the blood pressure is higher than a predefined value or lower; it alarms us. Or if the pulse goes up or down; it alarms us. "(Interview 19. Nurse)

"You can specify the distance of measuring the vital signs, for example, every 30min, every 5, every 10, and the device measures itself. "(Interview 11. Doctor)

The findings of this study showed that participants were satisfied with the existing digital systems. Moreover, they compared their digital system with other equipment and devices used in the UCCK or even other private hospitals, as follows:

"For the moment I think that this system is very good. Because in Kosovo there is not a better one. Now if we compare the public hospital and this one (.) only in foreign countries are these luxuries I can say. "(Interview 11. Doctor)

"I do not know any advanced technology used anywhere that we do not have it here." (Interview 3. Doctor)

The possibility of recording vital signs for 24 hours is seen as another advantage that the digital monitoring system offered to participants. Hence, doctors could get patients' files and read their values without being in the patient room. These files were downloaded and saved in every patient's folder. This was seen helpful also in cases of artefacts.

"Hence, the Holter is not something abstract.. but when you decompose the Holter; it is like an ECG. "(Interview 4. Doctor)

"They are objective data recorded on a disk for 24 hours. Normally, these digital systems are better because you can save [save data]. If there is any event especially electrical event of the heart with these monitors that are 24 hours recordable, we see that event." (Interview 12. Doctor)

Another advantage of using digital monitoring systems that participants of this interview study mentioned, was related to time savings. They mentioned that in cases of a high number of patients it was easier to monitor and measure the vital signs, for example:

"Simpler for us because it does not take us a lot of time." (Interview 17. Nurse)

"We measure using the monitors [digital monitoring system] because it takes time to measure with the manual." (Interview 19. Nurse)

All the above-mentioned comments present healthcare professionals' points of view on the benefits of using digital technology in healthcare. Nevertheless, participants had also concerns about the digital monitoring systems that they were using, which are important for discussion and consideration before proposing new platforms, as in this thesis.

5.5.3.3 Disadvantages

Besides the advantages that were listed in the previous section, the healthcare professionals' main concern of the digital monitoring platforms that they were using, was related to data accuracy. They all the time were comparing the values of the vital signs displayed by the digital monitoring system with the ones measured using manual devices. Even though, as confirmed by participants, there were not so many differences, for example:

> "*The manual devices show better the blood pressure than the digital one. In the context that it varies a bit for a percentage 2mHg (..)" (Interview 1. Nurse)*
>
> *"Patients also come and ask me if they can measure with this digital device [means various digital devices that are in the market and serve to measure blood pressure], it often happens that the specific device does not give me the confidence.. and I say to them to measure also manually." (Interview 2. Nurse)*
>
> *"We also noted that there were not many differences. Because it happens that when patients have low blood pressure, the doctors also want to measure manually to see the accuracy. And they say there is not a big difference." (Interview 21. Nurse)*

Some digital monitoring systems consist of various facilities such as cuffs, electrodes, or finger patches, hence, in these cases, it is important to know how to use them, or how to place them. For example, the position of the hand may be an indicator for the device not to display the correct value, as suggested by participants:

> *"The position of the hand should be in the same level with your heart. Because the blood pressure may not be accurate." (Interview 21. Nurse)*
>
> *"The other thing is that patients do not know how to measure it. Because every move of the hand leads to incorrect values of the parameters. So, in this case, the device does not provide accurate data." (Interview 25. Doctor)*

The electrodes that the digital monitoring system and Holter monitors had, were considered as annoying to patients, as explained:

> *"Perhaps it is a bit annoying because patients often in the morning when I go and ask them, they start "eh I could not sleep because of them. These wires, this device all the night did not allow me to sleep" [patient's words]. Maybe it happened that the patient moved the electrode, and the device generated a false alarm." (Interview 2. Nurse)*
>
> *"[Holter]The disadvantage is that it has wires- cables... for example if you want to have a shower you need to remove it and after you finish to put it again." (Interview 4. Doctor)*

The glue of the electrodes sometimes was removed for example from sweat, and the digital monitoring system was providing an alarm which was stressful for the patient and the healthcare professionals because the patient's condition was fine. This was considered an artefact, for example:

> *".. because these electronics when placed with electrodes they may have also artefacts. And every artefact (.) some devices read it as arrhythmias." (Interview 14. Doctor)*

> *"When the patient sweats, the electrodes may be removed. And for a moment it can show changes that are not accurate for the ECG. Or it displays an asystole while the patient is good." (Interview 16. Nurse)*

For the Holter monitors, participants mentioned also the problem of batteries. For long-time monitoring, for example, 72 hours, nurses said that they need to bring the patient to the hospital again to change the batteries so that they can last for 72 hours recording of heartbeats or blood pressure.

> *"Always their concern is if the battery will last for a specific period of time. Because for example 24-hour Holter, we have it very often. 48 hours that is also placed often. 72 hours (..) we have cases but they are rare. And for 72 hours you should tell the patient to come and make it 48 hours and then another 12 hours." (Interview 5. Nurse)*

Another disadvantage of the remote monitoring systems that healthcare professionals were using was related to their access to the information registered in the device, as explained:

> *"During those 24 hours we have no information about what is happening. So, we do not have access to his/her information while the Holter is away. Hence, there is no online monitoring." (Interview 4. Doctor)*

Hence, healthcare professionals could not see the values of the vital signs until the patient returned the device and they connected it with a computer to read the information.

5.5.3.4 Summary

From the gathered data of this interview study, it is concluded that healthcare professionals had experience with digital technologies, such as the digital monitoring system used within the hospital to continuously monitor hospitalized patients, the Holter monitors that were used to monitor patients outside the clinic for 24, 48, or 72 hours, and Pacemakers that were placed to regulate the heartbeats of chronically ill patients. These systems seemed to have facilitated their work and the health services provided to their patients. Nevertheless, Gagnon et. al. (2012) in their review concluded that the adaptation process of digital technology was complex and may be influenced by different individual and organizational factors. This was noticed also in this study. However, training has been suggested (Hilty et al., 2020) as a tool to facilitate the adaptation process, as confirmed by the participants. It is important to mention also that these participants were of different ages. Therefore, the adaptation process of digital technology did not appear to be influenced by the age of the healthcare professionals or their education level. This was concluded also in the study by Denga, Moa, and Liuba (2014).

In this context, Table 5.2 summarizes the advantages and disadvantages of the existing digital technologies applied in the setting of this interview study, that were discussed by the participants. Further to this, very similar findings were reported also by Spyglass (2021) which concluded that the use of remote patient monitoring platforms helps to enhance the patient-medical staff communication and, in this way, to reduce the need to physically see each other.

Table 5.2 Advantages and disadvantages of digital technologies already applied in the American Hospital in Kosovo

Advantages	Disadvantages
Possibility to set the measuring interval and automatic measurement of patient's vital signs	Data accuracy
Provision of alarms and red marks in the monitoring screens	Radiation or ray imitation that the device imposes due to usage of wireless communications
Possibility to summarize and display all the measured values in a small screen placed on the nurse's desk	Wires of the devices
The possibility to have a printed report as a summary of the patient's condition for the last 24 hours	Possibility for the electrodes to get removed and the system to provide a false alarm
Time-saving	The short lifetime of batteries
Better monitoring	Not being able to access patient information in distance
Facilitates the work of healthcare professionals	Hight cost
Enhanced healthcare services	
Safety feeling for the patient	

As seen in Table 5.2, besides the benefits that healthcare professionals mentioned there were also some details that they noticed during their work with the digital systems. These concerns have an impact on clinical decision making, therefore they need careful consideration. Similar findings were reported also by VivaLNK (2021), which concluded the financial challenges for the clinical implementation of distance-based and continuous monitoring solutions. From the patient's point of view, in their review, Cruz, Brooks, and Marques (2014) confirmed that remote patient monitoring platforms are cheaper than clinical ones. Nevertheless, around 90% of the participants in VivaLNK (2021) thought that continuous, 24-hour data, were more important than periodic information, which adds up to the benefits of using such platforms.

5.5.4 Wireless networks in healthcare

As presented in the previous section, the term digital technology incorporates various technologies or systems. Wireless networks can be used to make a digital system work more effectively. When mentioning the effectiveness of a system, it is meant the performance or in the case of this research study, user perception. In this context, this subsection briefly presents interviewees' attitudes to have a wireless-based system to provide better health services. More specifically, to address the concerns regarding the wires of the existing devices, as discussed in the previous section.

> *"The electrodes, they have wires and thus it is a burden for the patient (.) they make the patient immobile, mandatory to stay in the bed, not even move because the electrodes may move and an alarm may be generated." (Interview 11. Doctor)*

> *"[Holter] The disadvantage is that it has wires, cables... and as I said the software is arranged in such a way that enables 24 hours or 72 hours monitoring. Longer, it is difficult (..) as it has*

wires … but with something else that does not have wires, that would be for example a simple watch placed in the hand or a patch that can be placed on the skin." (Interview 4. Doctor)

In this way, healthcare professionals suggested that a wireless device would be more practical and easy to carry for the patient, for example:

"If the device would be wireless and everything would be fine, everything very simple, then it would be much easier and the patient would hold it with pleasure." (Interview 17. Nurse)

"And if I come to get information, I would say that it would be better without wires. It will definitely be better without wires." (Interview 7. Doctor)

"So, if it was wireless, it would be perfect. Because like this [with wired electrodes] somehow you are connected." (Interview 2. Nurse)

A nurse even thinks of wireless in the context of clearness of the area in the hospital, as declared:

"The fewer wires you have, I speak now regarding the sterilization part, the fewer cables in the ground that we would have, fewer infections would be there." (Interview 1. Nurse)

Nevertheless, healthcare professionals also discussed the accuracy of wireless devices. They could not perceive how something not connected to the patient body could be accurate and provide information for them, for example:

"But (..) I do not know, it does not seem to me, maybe it's accurate, now I cannot say something, but it does not seem accurate to me." (Interview 22. Nurse)

"I do not know how real [it means accurate] it can be." (Interview 8. Nurse)

Some nurses expressed their concerns also regarding radiation that may be related to wireless networks, as explained:

"If it would not contain many rays for example. Radiation." (Interview 17. Nurse)

"Because of radiation. Rays. It means how the rays affect the patient. It is better to have less radiation." (Interview 1. Nurse)

These are considered important details to include in the design of the sensor-based architecture, and also valuable feedback before proposing the sensor-based application that will provide monitoring for chronically ill patients. Hence, the following sections will briefly elaborate on the profile of these patients and the vital signs that are important for monitoring.

5.5.5 Profile of chronically ill patients

This interview study aimed to understand also the profile of chronically ill patients. Hence, before proposing the sensor-based architecture, it was considered important to identify the group of users and how the proposed platform will help them and address their needs. In this case, this interview study investigated the average age of chronically ill patients that were visiting the healthcare centre, their living area, i.e., if they were travelling long distances to come to the nearest medical centre, or the number of patients depending on the season or the period of the year.

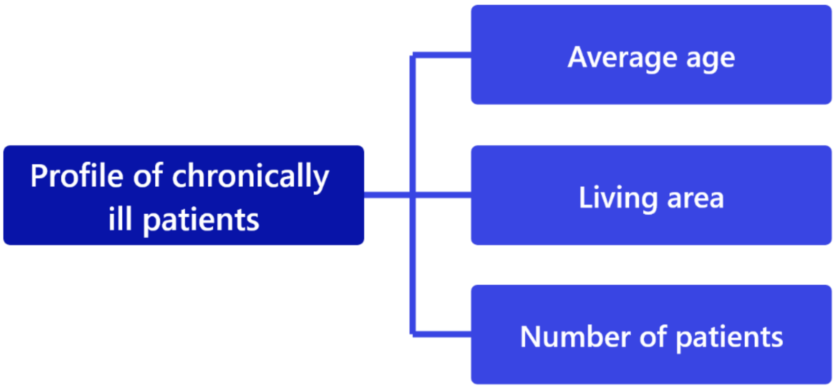


Figure 5.6 Sub-themes of the profile of chronically ill patients

Hence, as presented in Figure 5.6, this interview study identified three aspects related to the profile of a chronically ill patient. The participants discussed the average age of the patients visiting the medical centre, their living area, and the approximate number of those patients. These sub-themes are elaborated in the following subsection. Finally, the last subsection summarizes the findings related to the main theme, which is the profile of chronically ill patients.

5.5.5.1 Average age

The literature data in chapter 2, showed that the prevalence of older ages of patients with chronic diseases was decreasing, thus affecting also younger age patients. This was also confirmed from the findings of this interview study, as follows:

> *"One or two decades ago the highest prevalence of these illnesses was in the group-ages for example 50 to 60 years old, today is a trend of decreasing for this group-age and now already there is seen a higher incidence in the group age 45-55 years old… These diseases are becoming more and more manifested in slightly younger ages." (Interview 24. Doctor)*

> *"There are usually ages 40 to 70 years. Most of them." (Interview 12. Doctor)*

> *"Well, diabetes is a chronic disease. Somewhere it is after the age of 40-50 years old. We have also young patients, but they are very few. I can say mid-ages." (Interview 15. Doctor)*

> *"Usually, patients with heart disease are adults or older ones, at the age of 65. A smaller number of patients are let's say under 35 years old. Although there are, however they are few." (Interview 26. Doctor)*

Hence, participants confirmed that chronic diseases were recently affecting also younger age patients, for example:

> *"But there are times that we have also youngers, 20 to 30 years old. 30 years old are considered young to have coronary artery disease." (Interview 17. Nurse)*

> *"Even at the age of 29 we had a patient. We also had an 18-year-old patient." (Interview 21. Nurse)*

> *"Now it is also surprising as there are also young people. There are 30, 40, 60 of any age. We had even 18 years old patient for coronarography." (Interview 22. Nurse)*

"But we also had 25 years old patients with stroke." (Interview 7. Doctor)

Considering these findings, it is clear that healthcare professionals had a mixture of group ages with domination in mid-ages. Nevertheless, these results suggest that the sensor-based platforms would be useful not only to older adults with a chronic disease but they can be applied also to younger patients to monitor their condition or even get diagnosed at an early stage of the disease, considering the increased prevalence.

5.5.5.2 Living area

Chronic illness requires continuous monitoring and frequent visits to healthcare centres. Therefore, for a patient, it is important and helpful to have a medical centre near the living area. In cases of emergencies, or even when the patient has to make frequent visits, it is easier for them not to travel long distances to reach the healthcare centre. In this context, this interview study wanted to understand the distribution of patients based on the living areas. Hence, the findings showed the variety of patients' living areas. Most of the patients were travelling distances from other cities to come to Prishtina or even from other neighbouring countries, for example:

"There are cases maybe from neighbouring countries where they live. There were cases that they live in border areas and came here. There are also from Pristina, the district, but there are cases when they come from far away. "(Interview 10. Nurse)

"We have from all over Kosovo. There are patients from Kosovo, perhaps they come from Macedonia, or Albania, even from Presevo [Serbia]. "(Interview 11. Doctor)

"Yes, from all the areas we had. We had patients from Mitrovica, from Vushtrri, from Pristina, of course. From the rural areas of Mitrovica, from the countryside, Koshtova for example. "(Interview 21. Nurse)

The patients' living area is important as longer distances can cause delays which may impose complications in the health conditions of the chronically ill patient. This was confirmed also by the doctors of the interview study, as follows:

"*… there is a deadline from the moment when morphology is diagnosed, or from the moment that the symptomatology is developed, until the treatment. There is a time limit that needs to be considered so that the effects of the therapy are as effective as possible. This I think presents a problem. Because a patient who is let's say in Gjakova, or wherever he/she is, or Prizren; he/she will not be able to find a solution in the relevant regional hospital and he/she must come to us in Pristina [where the tertiary healthcare services are provided] and get the needed treatment. "(Interview 24. Doctor)*

"However, those who come from the rural areas, from other cities, obviously they are delayed more. They spend for example half an hour while they go to the nearest healthcare centre and then they need 1 hour or 1.5 hours to come to Pristina, meaning that they are late from patients that are in the district of Pristina who reach the doctor 1 hour before the others. "(Interview 25. Doctor)

The fact that Kosovo has just one public healthcare centre for providing specialized healthcare services is seen as a limitation in providing quality healthcare services to the whole population. This is considered as another factor that makes patients visit private healthcare centres. This was identified also during the interview study. A nurse confirmed that UCCK may not cope with all the flux of patients for specific medical services or tertiary requests, as explained:

> *"Well, because of the conditions in Kosovo, as known, not all public hospitals have the possibility of coronarography. Now even the UCCK when the device is working, it cannot cover all the cases. Because there is a huge number of requests [patients]. "(Interview 18. Doctor)*

This interview study revealed another interesting fact related to a patient's living area, as explained:

> *"Usually, (.) Especially (.) for ergonometry and for Holter ECG and Holter blood pressure we have more patients come from cities. Because they are passive, they do not walk, they are into offices, eat fast food that put weight a lot, the fat is introduced to them, then blood sugar. "(Interview 5. Nurse)*

This indicates that a patient's living style is also important when considering chronic diseases, which was concluded also in chapter 2, after the literature review. This is also supported from the Centre for Disease and Control Prevention (2017) which declared that 50% of adults aged 18 years old in the USA do not meet their suggestions for physical aerobic activity; and more than 37% of adolescents and 40% of adults eat less than one fruit or vegetable per day.

5.5.5.3 Number of patients

Another important factor that was investigated in this interview study, was related to the number of patients in the healthcare centres, considering chronic conditions as long-lasting diseases that need continuous management and frequent hospital visits. Hence, the findings showed that the number of patients depends from department to department. For example, in the Cardio-surgery department participants confirmed that the number of patients depends on their post-surgery conditions. If the patient's condition during the surgery was fine, they monitored for a while and then transferred the patient into cardiology or another department, as explained:

> *"During the day we may monitor 1, none, it happens that we have 3 or 4 patients. It all depends on their post-operative status. "(Interview 11. Doctor)*

While in the Cardiology department interviewees declared that there are patients that come and go, for example, they are transferred to the Cardio-surgery department or Coronarography unit:

> *"For sure five, but of course even more. Because it happens that we have more patients, up to 15, 13. "(Interview 16. Nurse)*

> *"Well now (.) the capacity of our unit is up to 10 patients. But there are cases when a patient comes out and another one comes in and replaces him/her. We had up to 13, 14 within a day. But on average I would say 10. On these two cold months and two hot ones of the year, we have more work. "(Interview 17. Nurse)*

> *"For example, during this time [winter] we had a lot of work. By this time, we had 79 patients. Every day we have 8 or 9. "(Interview 19. Nurse)*

> *"During this month [January 2017] we had many patients. 8, 9, 10 beds. "(Interview 21. Nurse)*

As this interview study included healthcare professionals that were working also in the public healthcare centre, they provided information on the total number of patients that they were visiting also there, for example:

> *".. on average on Friday, I have around, I can say, even 40. Although this is divided, from 09 o'clock to 14 o'clock we work two people. But often it happens that I work alone. But I can say 20-25 patients. Plus, in the private sector during the week I monitor somewhere 20-30 patients. So, during the week there are 50-60 patients that I see, advise and treat. "(Interview 15. Doctor)*
>
> *".. sometimes the work is like that, for example, in the specialist ambulance, I may have 20 or 40 patients. "(Interview 24. Doctor)*
>
> *"In the days when I have the specialist ambulant approximately, I have 20 patients in the ambulance. 20, 25… While the busiest day is the 24-hour care at the Cardiology Clinic that means that I probably have to check 40-50 patients within the day, and about 10, 15 of them may be filtered out to get hospitalized. Approximately. I'm talking about the public sector. "(Interview 25. Doctor)*

In general, the number of patients with chronic illnesses that are visited by healthcare professionals depends on various factors. As participants mentioned this number depends on the type of disease, the season of the year, the patient's age, and the patient's condition. However, the doctors working in the public healthcare centre confirmed that the number of patients there was higher compared to the private hospital.

5.5.5.4 Summary

Gathered data regarding chronically ill patients' profiles are considered very important information for the design of the sensor-based architecture. Therefore, having a view of the patient's average age, this study can propose an architecture that will suit their needs. Considering interview data, it is obvious that the average age of chronically ill patients is between the range of 35 to 80 years old. However, participants confirmed that happen to have even younger patients with symptoms of chronic diseases, thus the dissemination of ages is decreasing. Interviewees declared that the age of the chronically ill patient depends on the disease itself, or the cardiac pathology, and also on the age-specific incidence of the chronic disease.

The interview study investigated also patients' living areas or whether patients were travelling long distances to reach the nearest healthcare centre. The gathered data showed that patients came from all over Kosovo. Another interesting fact that the interview study revealed is related to patients that come from Albania, Macedonia, or even European countries to visit Kosovo's healthcare centres. Regarding European countries, healthcare professionals meant Kosovars living there, however they visit healthcare centres in Kosovo during their vacations.

Patients with chronic illnesses are considered to have continuous visits to healthcare centres. Therefore, this interview study investigated also the number of patients that each healthcare professional monitored or visited per day. As the study included participants that were working in the public healthcare centre too, they confirmed that the number of patients there was higher compared to the ones in the private hospital.

5.5.6 Vital signs to monitor for chronic diseases

Aiming to complete the puzzle of the sensor-based platforms for application in the healthcare settings, this study investigated the vital signs that the healthcare professionals needed for remote and continuous monitoring of their patients. Hence, having an idea of the existing digital platforms, and the profile of the chronically ill patients, this study continued investigating the key chronic parameters that may be included in the sensor-based architecture.

As presented in subsection 2.3.3 there is a list of chronic parameters that are important to continuously record and monitor, such as blood pressure, oxygen saturation, pulse rate, respiratory rate, and body temperature. These vital signs were considered important in detecting deterioration in patients with chronic illnesses also from Armitage, Eddleston, & Stokes (2007). Failure to interpret, read and monitor these parameters causes patients not to receive the appropriate treatment on time. Hence, this interview study investigated several factors for understanding how healthcare professionals were managing and recording vital signs of their chronically ill patients.

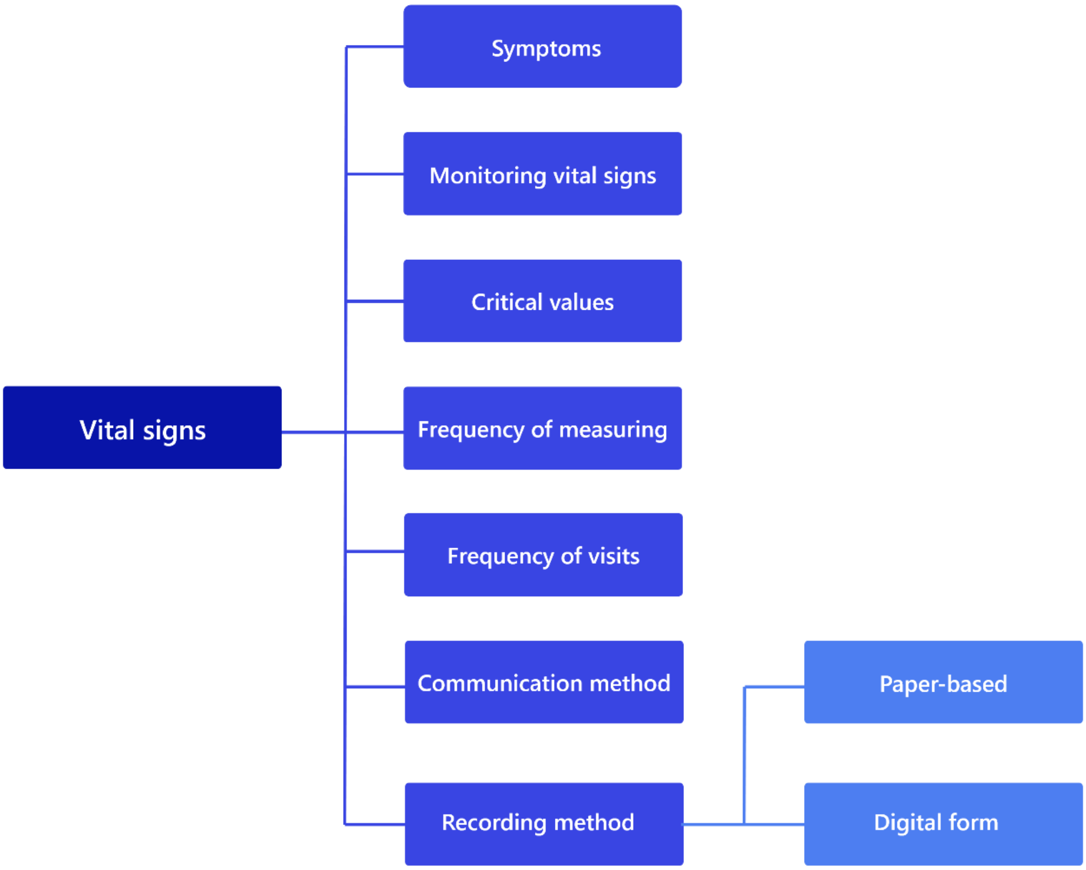


Figure 5.7 Sub-themes of the vital signs

After the data analyses process, the theme of the vital signs had some other related sub-themes as presented in Figure 5.7. A detailed overview of each of the identified sub-themes is presented in the following subsections (5.5.6.1 – 5.5.6.7). Similarly, the final subsection (5.5.6.8) summarizes the findings of the results for the theme of the vital signs.

5.5.6.1 Symptoms

This subsection provides information on the gathered data from the interview study related to the symptoms that lead to the early identification of chronic conditions. Here are included also the most frequent symptoms that healthcare professionals encounter in their chronically ill patients. Hence, here are discussed mainly modifiable factors because as a doctor mentioned:

> *"But I do not know how this device [the sensor-based platform] could affect unmodified factors, for example, inheritance, gender, or age. "(Interview 14. Doctor)*

Hence, as the findings of this study showed, some risk factors that do have an impact on the creation of a chronic condition were related to tobacco use, extreme alcohol consumption, lack of physical activity, and poor nutrition, as suggested:

> *"I would first say to stop smoking. Since smoking is the main cause that blocks blood vessels. There are others too. It's alcohol. There are also other things but especially smoking. "(Interview 20. Nurse)*

> *"Smoking is the number one risk factor. Physical activity has already proven to be a therapeutic measure. Even in the sick people and in the diagnosed ones with heart failure. "(Interview 24. Doctor)*

> *"Tiredness, sloth, pain, loss of strength, loss of walking force or physical strain, walking the stairs causes tiredness, sluggishness. "(Interview 25. Doctor)*

Other frequent symptoms that healthcare professionals encountered in their patients were related to hard breathing, chest pain, irregular heart beatings, and tiredness. As they explained:

> *".. for cardio-vascular diseases these are significant: the chest pain, hard breathing (..) and fatigue/tiredness (.) irregular heart beating. These are 4 symptoms that almost 90% of patients have. "(Interview 12. Doctor)*

> *"The most commonly known is the chest pain. Difficulty in breathing, body fatigue, but tightening of the chest is the foremost thing that forces patients to seek medical help. "(Interview 25. Doctor)*

> *"Well, (.) these of course have chest pain that goes towards the chest. This pain is when the hand and fingers start to numb, we know that the problem is related to the heart. They hardly can breathe and have pain. "(Interview 17. Nurse)*

> *"Some show that they have chest pain. Some say they have dizziness, have chest tightness, the symptoms are different. "(Interview 23. Nurse)*

Other participants mentioned also related factors such as hypertension or increased blood pressure or heart fibrillations, for example:

> *"Chronic diseases that are more frequent or perhaps that lead to these diseases are hypertension, diabetes. "(Interview 2. Nurse)*

> *"With high blood pressure, hypertension. Rhythm disorder. "(Interview 13. Nurse)*

"We often have patients with disorders of blood pressure. Also, with the disorder of rhythm of arterial fibrillation. This is the most common. As well as arrhythmias or different systoles. "(Interview 14. Doctor)

As participants suggested, some of the symptoms for early detection of chronic conditions were related to the monitoring of chronic parameters such as blood pressure or pulse. These were considered parameters that patients could monitor also themselves, and their values could be an indicator for better diagnosing the patient.

"They can measure the blood pressure and take regular therapy because most of the time they do not take it and then it becomes chronic. "(Interview 19. Nurse)

"To measure the blood pressure. Because when we get the history of the disease (.) Ok, some monitor their condition, use the therapy, some say –I have never measured the blood pressure until today that I came here- [patient's words]. Then of course also the pulse. "(Interview 16. Nurse)

From these comments, it is noticed that there are patients that monitor themselves very rarely or only when they go to a healthcare centre. Therefore, the proposal of a feasible sensor-based platform for monitoring chronic parameters would be a benefit also for these types of patients. Regarding diabetes, the triad was mentioned: polyuria, polydipsia, and polyphagia, meaning the large intake of food, drinking water, and frequent urination:

"When they arrive, usually come patients with tiredness, with apathy, weight reduction (.) concern regarding not-decreasing glycaemia from the pills that he/she gets. "(Interview 15. Doctor)

In these cases, the doctor mentioned that it was important to measure the blood glucose, however, even high blood pressure or fats can influence the blood glucose values, for example:

"They can have high blood pressure, or fats disorder, family predisposition. And those patients would be good to do a test and do their screening. "(Interview 15. Doctor)

"Nowadays we have diabetes as an independent risk factor for cardiovascular incidents. And when we return to this pathogenic entity, I can say that blood glucose values would be very important. "(Interview 24. Doctor)

Another important suggestion that a doctor gave during the interviews, had to do with the patient's situation either physical or emotional, and how this could affect the values of chronic parameters, as explained:

"The pulse is very variable. It is different when you are standing, sleeping, running, walking, having emotional stress, physical stress; it changes a lot. Or arterial blood pressure as well. Because these are very important to be monitored throughout the day. "(Interview 25. Doctor)

Hence, the healthcare professionals provided various examples of the importance of continuous monitoring of a patient's vital signs, which are also presented in the following subsection.

5.5.6.2 Monitoring vital signs

In the hospital where the interviews for this study were conducted, the vital parameters, such as blood pressure, pulse, oxygen saturation, temperature, and heart rate, were measured either using the digital monitoring system for hospitalized patients, discussed in subsection 5.5.3; or using the manual devices. Healthcare professionals mentioned also that they measure the value of blood glucose for diabetic patients.

> *"We monitor pulse, heart rate, arterial hypertension, and patient oxygenation; these are the most essential, called vitals. Also, temperature. These four vital parameters we monitor all the time. "(Interview 2. Nurse)*

> *"For us, it is very important the heart rate. Although I am not directly a cardiologist, but there are some disorders of heart rhythm especially atrial fibrillation, which is one of the main risk factors and the main causes of brain stroke. And a major part of the patients who suffer brain strokes, when they come here, we want to seek the cause ... we seek among other things, the rhythm of the heart or atrial fibrillation." (Interview 4. Doctor)*

As the interview study included various departments of the hospital, a nurse from the Surgery department also confirmed that blood pressure and pulse are important parameters to consider even after the surgery, for example:

> *"The primary is the blood pressure, and pulse." (Interview 8. Nurse)*

Some participants mentioned that the values of vital parameters are closely related also with the profile of the chronic patient, for example, the metabolism, age, the medication used, and disease characteristics, as explained:

> *"There are certain pulse rates that are considered normal. But these should be adapted for example to the patient's metabolism, physical activity, age." (Interview 24. Doctor)*

> *"To cardiac patients is the age, is the time when he/she had the first heart problems, how much is that heart damaged, what blood pressure, what pills has he/she used, what time he/she used the pills, then is the state of the lung, the condition of blood vessels, blood fat, blood glucose, all of these can complicate." (Interview 3. Doctor)*

Consequently, a patient's body or the condition of various organs also dictate the critical values of these chronic parameters and their frequency of measuring. Hence, the next subsections present details on the critical values of chronic parameters and their frequency of measuring them according to healthcare professionals' practices.

5.5.6.3 Critical values of vital signs

In subsection 2.3.3 were presented details on chronic diseases, including the vital signs that are usually monitored for these illnesses and their critical values based on literature data (Alecu et al., 2017; Blood Pressure Association, 2015; Kelly, 2006; Agrawal, 2006 Schutz, 2001). Nevertheless, this study aimed to understand also the clinical aspects related to the critical values of the vital signs. Hence, the findings showed that the range of normal values of chronic parameters may be influenced by the patient's body, for example, if the patient's organism is used to a higher blood pressure value, then that value becomes somehow manageable, as explained:

"Well now (..) it depends on what pulse the patient usually has. For example, in the books, we find the range for normal heart rate 60 to 100 bpm. But this is also in borderlines because there is a sportsman who has 45 bpm but he/she does not have any problem at all." (Interview 25. Doctor)

"For example, if the pulse value falls below 50 or 45 bpm we intervene immediately. If the pulse is over 120, tachycardia, there also we should intervene with therapy. However, it depends. If the patient says that also in the everyday life, he/she has low blood pressure, then it is simply his/her everyday life and we do not intervene. If he/she has the blood pressure very, very high, then we intervene with pills." (Interview 11. Doctor)

Regarding diabetic patients, there are some criteria when it comes to the normal range of blood glucose. According to a doctor:

"Sober [without eating] the glucose should be 6, or 7 millimoles per litter (mmol / l). The good one is 5, or 6, but depending on the patient's health status we set some criteria. For example, for a patient with kidney disease, we cannot require the patient to have glucose values 5, 6. Or if the patient is aged. To these patients, as well as another category of cardiac patients who have heart problems, or those who had a heart attack; we do not expect from them to have values such 5, or 6." (Interview 15. Doctor)

The critical values of the vital signs also indicate the frequency of measuring them. Therefore, the next subsection elaborates on the time interval that healthcare professionals measure a patient's vital parameters and the facilities they used to measure them.

5.5.6.4 Frequency of measuring vital signs

Continuous monitoring of chronic parameters may impact also the condition of the chronically ill patient. Now considering the setting of this interview study, the healthcare professionals mentioned that they measure vital signs once the patient is admitted to the hospital and after that, they said it is a rule of the hospital that vital signs should be measured no longer than every two hours, for a patient under monitoring with a stable health condition.

"Once the patient comes, we initially take a history." (Interview 9. Nurse)

"It depends on the patient's condition. If a patient is in good condition, they are measured every two hours. Hypertension is measured every two hours. However, pulse and ECG, 24 hours." (Interview 2. Nurse)

For critical patients, the healthcare professionals were measuring vital signs more often. Hence, the frequency of measuring in these cases depended on the patient's condition and the values of the chronic parameters. However, using the digital monitoring system they said that vital signs were on the central desk for 24 hours. In this case, they were referring to the central monitor that presented the summary of the individual monitors that were monitoring patients, for example:

"In patients with these diseases [refers to chronic disease] they are monitored continuously (.) it means even if you do not go every two minutes in the room, we see the values from the reception desk." (Interview 10. Nurse)

"Vital parameters are in the monitor [screen] all the time. I, whenever I have free time, I go through the rooms of the patients and see them [vital parameters] also here in the corridor are the parameters of each patient with the numbers of beds." (Interview 18. Doctor)

Considering these comments, it is understood that sometimes healthcare professionals do not need to go into a patient's room to see his/her condition as they have the vital signs displayed in the central monitor. The digital monitoring system enabled healthcare professionals to set the frequency of measuring the vital signs. Further to this, they could see the summary of the values or get informed by alarms in case of critical values.

"If they [patients] are hypertensive we program [the digital monitoring system] to measure the blood pressure every 5min or 10min." (Interview 20. Nurse)

"And there is also the possibility (.) for example for the blood pressure we have it as a rule to measure the vital signs every two hours. But if we see that the patient is not feeling well, then the monitor allows us to set the measuring interval." (Interview 17. Nurse)

Although this may indicate that healthcare professionals only get the values displayed without understanding their accuracy, they said that there are many cases when they also measured the vital signs using manual devices too. Moreover, healthcare professionals also see a patient's condition and ask about possible implications, as explained:

"*Initially when they [vital signs] are above or under normal values then there is an alarm on the patient's monitor that rings, indicating that something is not good. Then we go and ask for example when he/she has tachycardia- do you have any concern- [the participant asks the patient]. Usually, when the patient has pain, this pain causes the heartbeats to be quicker what can cause the tachycardia." (Interview 11. Doctor)*

"There are cases when we measure a patient's blood pressure with a manual device if we do not like that we see from the digital monitor." (Interview 17. Nurse)

Hence, these comments indicated that the frequency of measuring the vital signs may not be the same for all patients, and the possibility of the digital monitoring systems to change it, was considered as helpful and facilitated healthcare professionals work for monitoring especially patients in a more critical condition that needed more frequent measuring of the vital signs.

5.5.6.5 Frequency of visits

The healthcare professionals also discussed the frequency of visits that patients with chronic illness did in the hospitals. Hence, as they confirmed, the frequency of visits starts from every day up to once in six months, as explained:

"The visit depends. When he/she comes for the first time, the second visit is in a week. The third visit is in a month. And then it depends on the importance of the disease. Those patients who are more seriously ill once a month, others every two months, or once in six months." (Interview 12. Doctor)

"Approximately once a month or in two months. Depending on the pathology, once a year, or once every six months or less." (Interview 25. Doctor)

"Depending on the situation, I cannot say a certain time. From every day to once every six months." (Interview 6. Doctor)

Hence, considering chronic diseases, as the findings in the literature review chapter 2, showed, a patient will have frequent visits to the medical centres. Furthermore, as confirmed also here, a chronically ill patient should visit the healthcare centre at least twice a year. This was suggested also in the report regarding management of chronic illnesses published by Oklahoma Department of Corrections (2021), which reported quite similar values. In this report it was stated that chronically ill patients should visit healthcare centres at least twice a year; however, for some chronic diseases (e.g., blood pressures, blood sugars, peak flows) frequent monitoring was necessary.

5.5.6.6 Communication method

The communication method or truth-telling in healthcare is a broad term that includes several ethical problems. These problems have to do with the right of the patient or family members to get information about the patient's illness or diagnosis. Healthcare professionals, should understand the patient's condition and somehow foresee the risk of providing information. Therefore, there should be a balance between the healthcare professionals' obligation to inform the patient and the situation not to harm, and in this way, not to inform. Hence, this interview study investigated also the communication of a patient's health condition, as explained in this subsection.

In general, healthcare professionals declared that in cases when the patient asked regarding the values of his/her vital parameters they tell them. However, they confirmed that when the values were critical, they did not tell this to the patient. Healthcare professionals thought that communicating critical values to a patient may worsen his/her condition further, as explained:

"For example, if you tell them that they have high blood pressure they start worrying. But they ask and we should tell them. Just that we do not tell the values if they are too high because it only affects them for bad." (Interview 19. Nurse)

"Initially it is better to tell the parameters that we think are in the normal boundaries." (Interview 16. Nurse)

"We should be careful because if we tell him/her [the patient] then they can become worse because the patient thinks of his/her parameters." (Interview 22. Nurse)

These comments were further supported by doctors who were aware that the patient had the right to have information about his/her condition. However, the doctor confirmed that they are more open with family members:

"With family members, we should be more open even though the patient has the right; it should have complete access to what is happening to him/her." (Interview 18. Doctor)

Another doctor linked the idea of not telling the patient about his/her critical condition with the level of education of the population in Kosovo. Moreover, the doctor that worked in the public and private hospital, as well as a professor in the University of Prishtina, said that:

"Because if the patients are with a low level of education, they can commit suicide or I do not know what. They do not have patience." (Interview 12. Doctor)

Nevertheless, a nurse confirmed that patients have knowledge about the normal range of values of their chronic parameters as they are used to those values and have read about them, as she explained:

> *"He/she [the patient] knows whether it is a high or low value; because he/she is used to his/her condition. Has read. And often they know whether it is good or not good." (Interview 17. Nurse)*

The findings of this study, on communicating or not a patient critical condition, showed a diversity of participant's opinions and practices. Nevertheless, most of them agreed that informing a patient about a critical condition may worsen his/her health condition further, i.e., cause stress that may increase the values of the vital signs. Hence, in critical values of chronic parameters, healthcare professionals preferred to intervene with therapies or medication rather than to inform the patient about the condition.

Another important aspect related to the vital signs is their recording method. Hence, details on the recording methods, either paper-based or using the digital form, are elaborated in the following subsection.

5.5.6.7 Recording method

The recording method of a patient's vital signs was an important concept to investigate as it provided information on the attitudes of healthcare professionals and their experiences in using digital technology for recording a patient's data, and showed the current practices of recording that were applied. Hence, the findings of this study identified two underlying sub-themes of the recording methods theme, as presented in Figure 5.8.

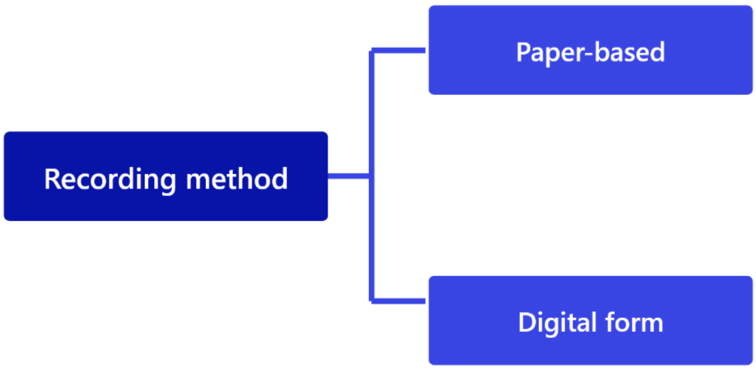


Figure 5.8 Sub-themes related to the theme of the recording method

Details of the underlying sub-themes presented in Figure 5.8 are discussed in the following paragraphs.

Underlying sub-theme 1: Digital form

The hospital was using a digital system, which showed a patient's data and the history of his/her examinations. A patient's data were entered into the system by administrative personnel while other tests, examinations, and therapies were entered by doctors. In this way, a patient had a history of the diagnosis and therapies used, as explained:

> *"The hospital has a software where are recorded data of all patients from the moment they come to visit. Starting from those personal, laboratory analyses, various recordings, various*

consultations, all are recorded in the program. Then also what we work on that patient, are recorded there." (Interview 3. Doctor)

"The doctor writes the report where it describes what he/she has done during the surgery, what he/she has used, it means it is in the software too." (Interview 1. Nurse)

The digital monitoring system used in the private hospital could print a 24-hours report of all the measured vital parameters for the specific patient, for example:

"The patient will have a written report generated in .pdf with all the needed material. Because every device gives it in that way. And has the commented results from every doctor. It means specific report." (Interview 14. Doctor)

Some participants compared their digital system with the one used in the public hospital:

"They [patients] have it as a folder, or how to call it (.) on the computer where are stored…especially in the American hospital they [patient's data] are stored strictly. (.) when I worked in the UCCK I wrote in the notebooks." (Interview 13. Nurse)

"In the clinic [public hospital] the nurses have the sheets that keep the records for each visit. Blood pressure, pulse, and others. But here [private hospital] the system is a little different. Every patient has his/her folder and every visit made from the doctor is registered." (Interview 25. Doctor)

According to the last comments, the personnel working in the private and public hospitals made a comparison in recording methods used in both healthcare centres. Furthermore, another participant confirmed that in the public healthcare centre, there is no such system:

"There is no Health Information System. Kosovo does not have it. The Luxembourg government tried something, but they have been drained and there is no health information system." (Interview 12. Doctor)

Underlying sub-theme 2: Paper-based

The setting of this interview study was using also paper-based sheets to record a patient's vital signs for a specific interval of time. Hence, nurses were going with the nursing sheets near the patients' beds and writing values they were seeing in the digital monitoring system or sometimes measuring them manually and then writing in their nursing sheets. In cases that they noticed irregular values, they were calling the doctor for further advice, for example:

"We have a nursing sheet that nurses keep here and that document every two hours, or every hour, or every 10-15 minutes depending on how the parameters are measured. We document in the nursing sheets." (Interview 10. Nurse)

"We have nursing sheets that we record all patient data. For example, the smallest details related to the patient, we should write them and inform the doctor, as he wants to know the patient's state or how the patient is." (Interview 20. Nurse)

"We have the nursing sheet for every patient. Whenever we measure the blood pressure, we write them. We write them in the list." (Interview 22. Nurse)

Some nurses preferred to write the values of vital signs on paper due to technology disadvantages or as they mentioned:

> *"...because the paper does not get lost. It is a fact. Perhaps using technology, it can happen a damage, a defect, or something... so we must write down on paper, and we have all on paper." (Interview 2. Nurse)*

> *"...because if it gets infected with a virus everything can be deleted [laughs] so better on the paper. It would be good I think, but it has its negative sides as we may lose all the notes. So, on the paper, it is better." (Interview 19. Nurse)*

The healthcare professionals' mistrust of digital technology was also identified in subsection 5.5.3.3. In this context, healthcare professionals tried to argue the use of paper instead of an electronic health record (EHR) system with the flux of patients, overloaded works, time savings that paper-based method offered to them, or even the data accuracy and unauthorized access to a patient data, as explained:

> *"That, of course, is very good [the digital form] but due to the flux of patients it is more difficult." (Interview 11. Doctor)*

> *"It is also the computer, but if you need to write many things, I believe that is a load for nurses. It happens very often with the programs that there is a virus or long waiting until the program starts." (Interview 2. Nurse)*

> *"Time yes. Because for example, I am speaking for myself, it happens that I get the patient's file and I go to the patient. In front of the patient, I write. And I also monitor them. In the computer, of course, I guess I need to leave the patient, to put my head on the computer and to login in there [laughs]." (Interview 16. Nurse)*

> *"I do not think it's more accurate than writing." (Interview 22. Nurse)*

> *"Perhaps we are used (.) on the paper you do it more quickly. Because to log in the computer, it takes you time. However, with the letter you are in front of the patient, you look there and you write it immediately." (Interview 23. Nurse)*

Regarding access to a patient's vital signs, during the time that the researcher was in the hospital conducting the interviews, it was noticed (this can be considered as a sort of observation) that any healthcare professional had access to the patients' files within the same department. Hence, the paper-based method would not guarantee the security of the patients' data. Moreover, another nurse confirmed that less paper is better and continued by telling also regarding her/his working experience in Germany:

> *"Less paper is better. We save the environment too [smiles]. But we are a developing country and it is normal that we still need to write. In Germany, we used less paper. It means that most of the data were carried also in computers." (Interview 1. Nurse)*

In this way, the interview study revealed that healthcare professionals were using two forms of recording patient information, at the same time. Hence, the paper-based method was mainly used by nurses to write down patient vital signs for a specific interval of time (i.e., every two hours or more often), and doctors were using the digital system to record patient therapy, tests, or other examinations performed in the hospital.

5.5.6.8 Summary

Findings of this interview study on the usual symptoms that were encountered in patients with a chronic illness were related to tiredness, chest pain, hard breathing, irregular heart beatings or fibrillation, and increased blood pressure. Similar symptoms were also reported by the Centre for Chronic Disease Prevention and Health Promotion (2009). Therefore, healthcare professionals suggested continuous monitoring of the values of chronic parameters such as temperature, blood pressure, pulse, heart rate, oxygen saturation, and blood glucose. Regarding the critical values of these parameters, the healthcare professionals confirmed that the normal range of values may be a bit flexible as it depends on a patient's body, for example, if a patient's organism is used to a higher blood pressure value, then they become somehow manageable for the organism. In such a case, the healthcare professionals said that they may not react with therapies as that is seen as a usual condition for the specific patient.

In the literature, there is no evidence-based research that proposed how often to measure the vital signs of a chronically ill patient (Storm-Versloot et al. 2014; Miltner, Johnson & Deierhoi 2014). This was also confirmed in this interview study. The frequency of measuring chronic parameters in the setting where the interviews were conducted, was not a fixed interval. Most of the participants confirmed to measure the vital signs every two hours, and in cases of critical values, they measured them more often. The digital monitoring system that the hospital was using, enabled healthcare professionals to set the time interval when to measure automatically the vital signs of their chronically ill patients.

The frequency of visits was another topic investigated by this interview study. Hence, it was evaluated as important to understand how often do chronically ill patients visits the healthcare centre. The findings of this interview study on this context revealed that the frequency of visits varied based on a patient's condition and if further examinations were needed. On average, the frequency of visits was from every day to every six months.

In critical conditions, after seeing a patient's condition and having measured the vital signs, the healthcare professionals needed to decide whether to communicate this with the patient or not. Hence, truth-telling was discussed in this study as an emerging technology acceptance variable that was important for evaluation, especially when investigating the adoption and acceptance of digital systems into the healthcare setting, where the patient has access to his/her medical condition. In this regard, the participants of this study declared that in critical situations, they preferred not to tell the patient about the condition but to react with therapies or medication. According to them, informing a patient about this case may worsen his/her medical condition further, i.e., cause stress or increase the values of the vital signs.

Nevertheless, healthcare professionals will have to record a patient's condition or every detail that is related to them. Tysinger (2015) declared that digital technology in healthcare has affected data collection, data recording, and the documentation of data. The hospital where the interviews were conducted, was using a digital system to record patient information, i.e., details regarding the therapies or medication, as well as a doctor's comments. For hospitalized patients, nurses confirmed that they were using the paper-based method to write the values of the vital signs. In this context, nurses were strongly supporting the idea of using the paper-based method instead of an EHR system. They argued the use of a paper-based method instead of a digital form, with the flux of patients, overloaded works, time savings that paper-based method offered to them, or even the data accuracy and unauthorized access to patient data.

5.5.7 Distance monitoring of chronically ill patients

After understanding the profile of chronically ill patients, and the vital signs that healthcare professionals monitor for these patients, this study continued investigating the current practices and future implications of distance-based monitoring. Hence, to answer the research questions (subsection 2.8.3) of this thesis, it was important to understand healthcare professionals' attitudes, adoption, and possible experience in providing distance-based monitoring for their chronically ill patients. Therefore, findings related to distance monitoring of chronically ill patients, are elaborated in this subsection.

In this regard, when healthcare professionals were asked how a set of measurements coming from a sensor-based platform would affect the distance-based monitoring of their patients, they explained as follows:

> *"I think it would be something very good, very facilitating perhaps and it would increase much more the effectiveness and productivity of the treatment." (Interview 24. Doctor)*
>
> *"Recently for diagnosing the myocardial infarction, the application of therapy in distance has yielded very good results. So, it is indisputable, the positive effect of remote monitoring." (Interview 26. Doctor)*
>
> *"I think it's better to monitor even in the distance. To have a view of the parameters, and to see which therapy is affecting better. It is also easier for the doctor if the patients are monitored continuously." (Interview 21. Nurse)*

Therefore, these comments indicated a positive attitude of healthcare professionals towards remote monitoring. However, there are also important implications and remarks that this study considered through the sub-themes that emerged after data analysis, as presented in Figure 5.9.

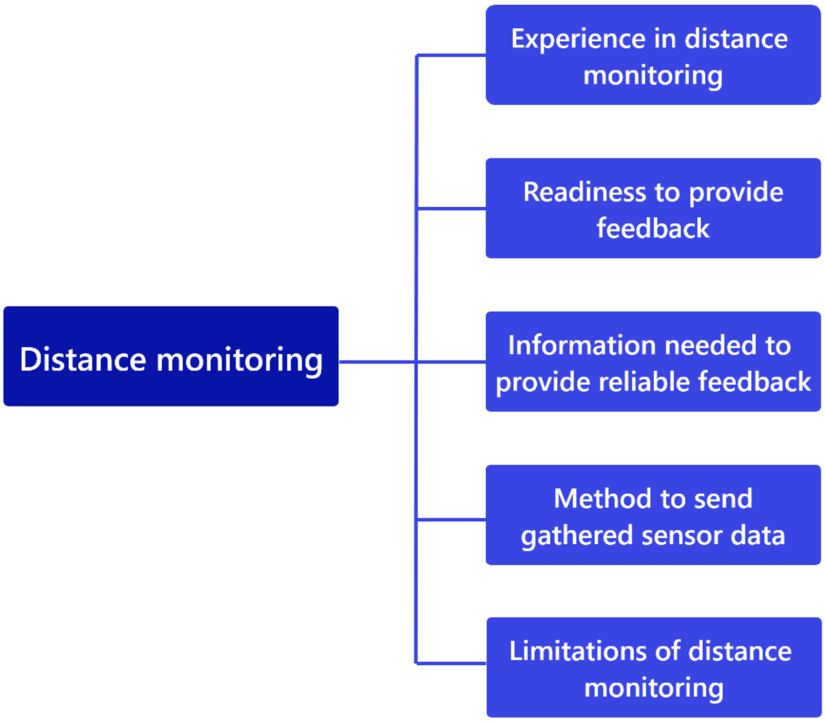


Figure 5.9 Sub-themes of the distance monitoring

The emerging sub-themes presented in Figure 5.9 are discussed in detail in the following subsection. The last subsection, 5.5.7.6 summarized the findings of the distance monitoring theme.

5.5.7.1 Experience in distance monitoring

While discussing the remote monitoring of chronically ill patients, the healthcare professionals elaborated the use of Holter monitors (i.e., subsection 5.5.3) as the current practice of remote monitoring. Nevertheless, using the Holter monitors (for 24, 48, or 72 hours), the healthcare professionals did not have access to the patient's vital signs or other information about his/her condition. Therefore, the patient had to bring back the device for the medical staff to connect it with a computer and read the recorded data.

The healthcare professionals also confirmed that they were receiving phone calls from their patients. Hence, a patient was calling or writing to them to inform about his/her values of the vital signs, possible reactions of therapies, informing about the test results, or to consult on therapy changes (i.e., increase the dose of a medication, or not). In these cases, the healthcare professionals were used to communicate with the patient and were providing advice or feedback at a distance, as explained:

> *"..yes it happens sometimes, rarely, that they call me on the phone. They say to me I have this problem; I have that problem." (Interview 12. Doctor)*
>
> *"There are many cases. Not one, but there are many cases that should be monitored and each tells us from home what the problem is. "(Interview 14. Doctor)*
>
> *"Many. They are tiring. Because I give the phone number and some get very close (.) they really overload me. Now they write me also on Viber. I try to answer them shortly. For example, some patients say: I have glycaemia 20 what to do, how units to get- [patients say]." (Interview 15. Doctor)*

"Yes, it happened. Some patients even send the ECG to me and require feedback through Viber." (Interview 25. Doctor)

Following are listed the most common cases why patients call or write to their healthcare professionals while at a distance:

- disorder of vital parameters,
  "Usually when they [patients] detect any disorder of their parameters. Especially of arterial blood pressure and heartbeat disorder, their rhythm… many call on the phone and think something extraordinary is going on or something that has not happened recently. "(Interview 24. Doctor)

- complains about chest pain or heart problems,
  "Well mostly because I'm dealing with this pathology, they do not call for something else but for chest pain, heart problems." (Interview 25. Doctor)

  "Perhaps a patient that is a little more concerned, having more fear. Yes, it happened that the patient called and considering my competencies and knowledge, I gave advice." (Interview 2. Nurse)

- therapy,
  "Or - the pill that you wrote to slow the heart rhythm, as I have it beating fast, I am using it but I feel that my heart is still beating fast, how to continue? These are those (.) the main ones or something very similar to what patients call the most." (Interview 24. Doctor)

  "Probably only about the therapy. How to use it." (Interview 16. Nurse)

  "For the therapy, it has happened to call me and ask." (Interview 23. Nurse)

- Holter monitors,
  "The day before yesterday I had a problem, a blood pressure Holter and in a moment the patient either he/she did not have the hand in the right position." (Interview 5. Nurse)

  "Or for example, (..) it is a device [Holter device] that there is no light and there are times that patients have called saying that it is not recording. "(Interview 13. Nurse)

These practices happened mostly to specialist doctors, for example, Cardiologists, because as the findings showed the general doctors that were working within units or departments of the hospital, declared that it did not happen to them to get contacted by the patients, for example:

"To tell you the truth it did not happen to me. Because I am the unit doctor. It may happen to the specialist doctor." (Interview 11. Doctor)

"They [patients] call their doctors who have examined them all the time." (Interview 17. Doctor)

Similarly, some nurses declared not to happen to them to get contacted by a patient, for example:

"No. We nurses, not." (Interview 10. Nurse)

"It never happened to me." (Interview 22. Nurse)

"Usually they [patients] contact doctors about their condition. Since we are not entitled to give a lot of information about the patient's condition." (Interview 19. Nurse)

This may be due to the practice of the hospital that nurses were not allowed nor had the right to advise patients by phone. Hence, in case of remote communication, they were suggesting to the patient to come to the hospital or sometimes call directly the doctor, as confirmed:

"… we have no right to give any advice or something. For this, we have the doctor. "(Interview 20. Nurse)

".. yes, I would redirect that to consult his/her doctor. Although we know many things, but we do not have that right. We do not have that competence. "(Interview 21. Nurse)

"I would personally tell him/her to come back to the hospital. I do not have the right to say something." (Interview 22. Nurse)

Consequently, the findings showed that healthcare professionals had experience in remote monitoring (using Holter monitors) and communication with their patients. Most of the nurses declared not to be allowed to provide feedback or advise to distance-based communications with patients, however, this was not the case with the doctors, who declared to share information with the patient also at a distance. Nevertheless, the current practices of communication did not allow the medical staff to have real-time and continuous monitoring of their patient's vital signs. Therefore, this study further investigated the medical personnel's readiness to provide feedback to the sensor-based data, as elaborated in the next subsection.

5.5.7.2 Readiness to provide feedback

This study found interesting results when investigating the healthcare professionals' readiness to provide feedback to distance-based patients if they receive their vital signs from a sensor-based platform. Considering also previous opinions of nurses and their competencies, most of them declared that they cannot provide feedback to the patient even having the values of his/her vital signs. Furthermore, they were delegating this responsibility to doctors, as explained:

"I do not know, because for this case probably the most competent person, is the doctor. Because for the disease and all these parameters he [the doctor] evaluates the therapy the patient should use." (Interview 10. Nurse)

"Information through the phone is not allowed at all. It's strictly forbidden. And I, as a nurse, do not have the right to interfere in doctor's therapy. So, I have to consult with the doctor. Without consultation with the doctor, we cannot do something." (Interview 21. Nurse)

"I would advise contacting the doctor. Because the doctor is the one who assigned that therapy and he knows whether to continue or stop it." (Interview 23. Nurse)

Nevertheless, nurses' competencies or responsibilities were not so clear because other nurses declared that they would provide information after having a summary of the values of the patient's vital signs, for example:

> *"In case that he/she [the patient] sends us the history of blood pressure, you already see them, and you see what blood pressure he/she had, what pulse he/she had, and of course to explain how to get the therapy and then at what time, which is of course very easy." (Interview 16. Nurse)*

> *"Yes [convincing]. Considering my nursing aspect, I will tell. It has a half-pill for hypertension. And I would ask if there was any concern, or what the patient has eaten. And with the knowledge I have, I could tell the patient to increase the dose of the pill." (Interview 2. Nurse)*

Similarly, other participants were ready to provide feedback to remote patients, furthermore, they explained how beneficial it would be to a report of values of a patient's vital signs also at a distance, for example:

> *"It would be much better. Because you notice it somehow, you see. Especially now how it is called this, telemetry." (Interview 26. Doctor)*

> *"A lot. When he/she comes with information it is completely different, altogether. It helps a lot when you have information. When you have more information on glycaemia measurements. It helps us even when they come with paper-based glucose history, including for example the day, the time, minute." (Interview 15. Doctor)*

> *"Yes. It would be much better. A lot better.. for example when a patient says to me personally that I have a change.. or I feel more frequent heartbeats, some patients express it in this way- it seems that my heart will go out because I have very frequent heartbeats- [the patient says]. But he/she does not know the exact number of that beating. How much does the heart beats per minute? Once they express in this way.. if there were devices, they would be more documented, would be more accurate." (Interview 9. Nurse)*

Nevertheless, participants discussed the accuracy of the gathered data, which may be a limiting factor for providing feedback to distance-based patients, as elaborated:

> *"This will have a positive impact only in those cases (.) when I would know that the device that has measured these signs, vital functions, parameters in fact; is automatic, so no manual. The patient has not measured them himself/herself. Because in the market we have tension-meter that are automatic but are not accurate. If this device [the sensor-based application] (.) would prove that it is safe, accurate, it would be a relief for both sides." (Interview 18. Doctor)*

> *"If it is a very trustworthy application or that has been verified. Approximately, because 100% none of them is verified. I believe it would be very easy. Much easier." (Interview 25. Doctor)*

The data accuracy presents a key parameter for providing feedback to a patient at a distance, considering that the medical personnel cannot see the patient but they only see the values of the vital signs, and they should be very accurate in order not to cause misunderstandings, or even harm to patients. With that being fixed, healthcare professionals were willing to provide feedback, considering that they were already communicating with the patients remotely. Moreover, a doctor took an example on how he would schedule appointments if a patient's vital signs will not be within their normal range of values, for example:

"And now even having tens or hundreds of patients... there is nothing urgent for example if at 9 am he/she [the patient] had a rhythm disorder and I see it at 9 pm; after 12 hours. I sit in a certain part of the day and I see it, and I call the patient to come tomorrow because we need to talk and discuss what happened this morning." (Interview 4. Doctor)

Therefore, the findings of this interview study identified current practices of remote communication and provided information and guidance on future proposals for remote monitoring platforms to facilitate distance-based communication between healthcare professionals and patients and improve their wellbeing. The next subsection provides further details on the information that healthcare professionals need to provide reliable feedback to their remote patients.

5.5.7.3 Information needed to provide reliable feedback

This subsection elaborates the findings of this interview study on the information that healthcare professionals need to provide reliable feedback to their remote patients, considering their readiness to do so, as presented in the previous subsection 5.5.7.2.

Healthcare professionals' comments and feedback may influence a patient's condition while he/she is at a distance. Thus, it is very important to provide accurate information, and descriptive values so that medical staff can provide reliable feedback. In this way, for a chronically ill patient, participants declared they needed to have the values of the vital signs, heart rate, blood pressure, oxygen saturation, pulse, as follows:

"Mainly for the heart functioning we need three parameters: heart rate, blood pressure, and oxygen saturation. These are the most important parameters of a chronically ill patient." (Interview 12. Doctor)

"ECG data, the state of the patient and blood pressure. Well, there are included also these other directions (.) because we need to look at the patient's saturation, pulse." (Interview 14. Doctor)

Additionally for diabetic patients, it was suggested to provide information also about blood glucose, as explained:

"Blood pressure, saturation, frequency, but I do not know now how far the technology can reach. For example, to measure also the level of glucose in the blood. It would be very important for patients with diabetes." (Interview 18. Doctor)

As the above comments show, the healthcare professionals mentioned the basic vital signs that they also monitor in their hospitalized patients, as elaborated in subsection 5.5.6. Therefore, the values of the key chronic parameters such as blood pressure, respiratory rate, heart rate, temperature, pulse, and blood glucose, were needed to provide reliable feedback to a chronically ill patient at a distance. Nevertheless, considering the sensor-based platform that this study proposed in chapter 6, it is important to note that it includes the measurement of the vital sign for which the respective sensor existed, for example, during the implementation period (the year 2016), there was no certified or approved sensor for blood glucose, as the literature review also confirmed (section 2.7).

5.5.7.4 Methods to send gathered sensor data

As the previous subsection identified the information that healthcare professionals needed to provide reliable feedback to their patients, this subsection will present the findings on the methods that are more appropriate for the healthcare professionals to use and those that they access more frequently to see a patient's condition. Hence, participants mentioned various digital platforms that they would like to receive the gathered information from the sensor-based platform which present a patient's vital signs, as follows:

- Email
  "Now we have these smartphones (.) you can also send by email; I think that it is a good approach. Now we all are using the latest technology. We all have hospital email, personal, and during all the time, we communicate by email, every day." (Interview 10. Nurse)

- Phone/Viber
  "Depending on the patient's condition. For example, hypertension cannot wait long, therefore, the phone is a little faster. Through phone or Viber probably to send them." (Interview 2. Nurse)

  "Phone maybe would be the fastest." (Interview 12. Doctor)

- Specific phone application
  "Because for example, until you go and search through e-mail, to find the patient who sent, when did he/she send, you can waste time. While there may be a special application about that, then it is much easier to find information quickly." (Interview 9. Nurse)

  "… to have an app on our phones or our computers so that when we want to look at, for example, x-patient to see how the parameters are, or to have the possibility that we in our application to arrange that if the patient has rhythm disorder or acceleration of blood flow, then to have an alarm or a pop-up, so that to access quickly and look at what is happening." (Interview 4. Doctor)

The above opinions show that healthcare professionals prefer the usage of mobile devices instead of computers, for accessing patient vital signs. This may be related to the current practices that they are used, for example, as a doctor also demonstrated the current communication with a patient through Viber, as follows:

> *"Now, for example, since we are here, I have a case that has sent me through the phone on Viber the tests [shows in his/her phone]. We have recommended to this patient to perform some tests. He/she has done them and now says if I can see if they are good or not. This is a good method." (Interview 26. Doctor)*

All these comments, opinions, and current practices provide helpful information for this study and also future ones that aim to propose remote monitoring platforms. Further to these suggestions, participants also discussed the limitation of distance monitoring which are important to consider and are presented in the next subsection.

5.5.7.5 Limitations of distance monitoring

The healthcare professionals of this interview study did not have experience in using a sensor-based platform for real-time and distance-based monitoring of their chronically ill patients. Hence, when discussing the limitations, they could only foresee possible limitations or express their opinions, as explained:

> *"Look, since we have not had such cases I cannot say it correctly. Because I cannot know. Because to us [means in Kosovo] working as a doctor is a bit harder. Why? Our people are changing their words. He/she [the patient] does not act as you told him/her [the patient]." (Interview 26. Doctor)*

In this context, participants proposed the documentation of the data, or the communication with the patient, either as a written report by both sides, to avoid misunderstandings or changing words. Furthermore, public regulations or government procedures would also be helpful, as explained:

> *"You give in the cabinet the same comment, the same assistance that you can give also through the telephone. But the evidencing of this is not done anywhere. You cannot leave for 24 hours your phone to get recorded by these (.) information media so that to get proved that you have been correct." (Interview 14. Doctor)*

> *"The patient can contact us but we have not regulated it with law. Because if you say to take this therapy, he/she gets it and it may occur any hypotension or any other problem then you should take responsibility, because- the doctor said so and so- [the patient says]. And we still have not regulated this system to access the patient. These are government things; I do not know how it is." (Interview 14. Doctor)*

> *"That should be regulated by the law." (Interview 15. Doctor)*

The reasons for possible misunderstandings between the healthcare professionals' feedback and patient practices, may be related to the patient's education and maturity to obey doctors' suggestions, as a nurse said:

> *"I do not believe that would result for good [that would have good results]. Because many patients do not take the therapy that is needed. "(Interview 17. Nurse)*

Another important factor that would also limit healthcare professionals from providing feedback at a distance has to do with data accuracy, as explained:

> *"Is the measurement done well.. also these digital cuffs.. there are cuffs that very often are coming with wasted battery, or the way of charging, or the cuff is not connected well. That would make me doubt whether it is correct. If I would tell the patient to take another half pill, it would lower the blood pressure; and now is that blood pressure accurate or not. "(Interview 17. Nurse)*

> *"Because it is not the patient's competence to refer his/her parameters. He/she may refer them incorrectly and have no-fault. "(Interview 24. Doctor)*

The doctors' commitments and time present another possible limitation for providing feedback to remote patients, for example:

“..yes it would bother me. Technically (..) I do not have the physical opportunity to follow all the patients at any moment, for any alarm. “(Interview 6. Doctor)

Many healthcare professionals mentioned that doctors are overloaded with work in the clinic and maybe they cannot monitor their patients also at home. Some also proposed alternative methods for responsible persons to monitor patients at a distance, for example, the family doctor, younger doctors without academic obligations, or specialized nurse, as explained:

“However, with the commitments that I have, this system [the sensor-based platform] I believe that for me it would not be very applicable. It would be more applicable to young doctors who have just a job. For example, that deals only with cardiology. It means they do not have academic commitments, etc, etc. “(Interview 12. Doctor)

“Maybe it will help also the doctors but I do not know if they have time to look at it.. that is something else. During working hours, you cannot monitor the patient [it means remote patients]. But family doctor yes. “(Interview 1. Nurse)

“Continuously, 24 hours, I do not believe that we have the opportunity. Because if we consider every patient, we may have dozens or hundreds of patients.. I do believe that we would have the opportunity to monitor all the time. Now is it worthwhile to get a person to look these for you or any nurse, these are organizational issues. “(Interview 4. Doctor)

Besides these, for the healthcare professionals, it was important to consider also the time of contacting them, the importance of the call, and the method of communication, for example:

“But sometimes the patient does not have limits. Calls without time. Writes things. The time and importance of the call. If it would not matter. If it was a simple question that would probably receive a response from ordinary people. The importance and time. The method of communication. This also matters. Because I do not know if it is a real patient or not.” (Interview 18. Doctor)

“Maybe a limitation would be the fact, where I am and what am I doing. “(Interview 24. Doctor)

Considering the last comment, the doctor thought that having the sensor-based application would somehow release them from the burden that a patient will call during an inconvenient time or disturb them. Hence, healthcare professionals would see his/her values of vital signs even remotely and advice based on them. However, while talking about chronic diseases, the values of the vital signs may be fluctuating, and in some cases, it would be difficult to provide feedback to these patients. This was identified by healthcare professionals who mentioned that in those cases they may not be able to provide information in distance but have to say to patients to come and visit the doctor, as explained:

“If there are changes in blood pressure or pulse. Then I will not be able to say something for sure (.) maybe without coming and consulting the doctor. “(Interview 16. Nurse)

In this context, it is concluded that data accuracy, healthcare professionals’ available time, if the patient will obey to healthcare professionals’ words and advice, the time of contacting healthcare professionals, the importance of call and the method of communication; are some of the possible limitations of distance monitoring. Furthermore, the findings here related to the creation of regulations and governmental procedures, present an important suggestion for improving remote monitoring and communication before proposing sensor-based platforms. This is included as a suggestion for policymakers, part of the contributions of this thesis (chapter 9).

5.5.7.6 Summary

This section provided the interview study results on the theme of distance monitoring. The aim was to understand healthcare professionals' experience, current practices of remote monitoring, and attitudes towards sensor-based platforms that would provide them with remote and continuous monitoring. Hence, the findings on this theme, showed that healthcare professionals had experience in monitoring patients at a distance (i.e., Holter monitors) and communicating with them (through the phone). Some of the reasons why patients contacted healthcare professionals were related to the disorder of their parameters, having chest pain or heart problems, therapies, and placement of Holter monitors.

The findings of this interview study identified contradictory opinions of nurses regarding their experience in monitoring patients at a distance. Some nurses declared they do not have the competencies to provide information to patients at a distance. However, the other group confirmed that they talk with patients through the phone and advise them according to their knowledge in things that they can help. But generally, most of them tried to delegate the responsibility to doctors, because as said, they cannot intervene in doctors' therapy.

A similar issue was identified also while trying to understand healthcare professionals' readiness to provide feedback to patients with chronic illness in distance. Doctors were used to getting phone calls and messages from their patients and in these cases responding to them. They even thought that getting values of the vital signs through a sensor-based platform would be better for providing more reliable feedback. However, data accuracy was raised as a factor that may limit them to provide information to patients at a distance. Other limitations were mentioned also: the healthcare professionals' available time, the patient collaboration, i.e. if the patient will obey healthcare professionals' words and advice, the time of contacting the healthcare professionals, the importance of the call, and the method of communication. Further to these factors, participants suggested that the remote communication and monitoring of patients, should be regulated by law, and governments procedures should be set to avoid misunderstandings and protect both parties, the healthcare professionals and the patient.

5.5.8 Sensor-based platforms

All the previous themes (digital technologies, profile of chronically ill patients, vital signs for chronic diseases, and remote monitoring) were investigated to gather information for proposing a sensor-based platform that will suit the needs of the healthcare professionals, comply with their current practices, consider their suggestions on further improvements related to remote monitoring of their patients, and overall facilitate their work and improve the patient care. Hence, the findings that will be presented in this section, are related to the application of the sensor-based platforms for remote and continuous monitoring of chronically ill patients, and they present contributions to this research area for a SEE developing country, Kosovo, considering that no previous, related, study was conducted in this regard.

The setting of this study was already using some forms of sensor-based devices as discussed in subsection 5.5.3. Hence, the hospital was using a digital monitoring system to continuously monitor hospitalized patients. This system within its components had sensors that enabled in-hospital monitoring. Further to this, for diabetic patients the hospital was using another sensor-based platform, as follows:

> *"It is CGM- continuous glucose monitoring. That is (.) actually like a sensor, and it is connected with the computer, and all the data are displayed in the form of a graph, it is extra [means special]. But it is too expensive. We made five, six measurements. We have the device. The patient wore it for 5, or 6 days." (Interview 15. Doctor)*

The CGM was used to remotely monitor the blood glucose levels and could record a patient's data every 5 minutes. Similar to the Holter monitors, the medical personnel did not have access to these data until the patient brought back the device to the hospital and they connected it with the computer.

Pacemakers presented another example of the experience of healthcare professionals with sensor-based applications. Pacemakers are devices that sense heart rate and then the device stimulates heart muscle to pump blood in the heart as if it was a normal heart rate, so it senses and paces the heart rhythm (Wilkoff et al., 2016), as explained by participants:

> *"The pacemaker is placed in the operation room by the doctor. It is a device placed on the chest on the left side [demonstrates] to keep the pulse at normal values." (Interview 19. Nurse)*

> *"Pacemaker can be both temporary and permanent. It is placed in patients who have a low pulse, low heart rate, or high heart rate, for example." (Interview 21. Nurse)*

These comments confirmed healthcare professionals' experiences with sensor-based platforms, even though they were not in real-time and the monitoring was performed for a shorter interval of time. Nonetheless, this facilitated the investigation of participants' attitudes towards remote and continuous monitoring through sensor-based platforms. Hence, the data analysis process enabled the identification of important aspects related to the proposal, design, and possible challenges and concerns that should be considered before proposing such a platform. These emerging aspects are summarized as sub-themes and presented in Figure 5.10.

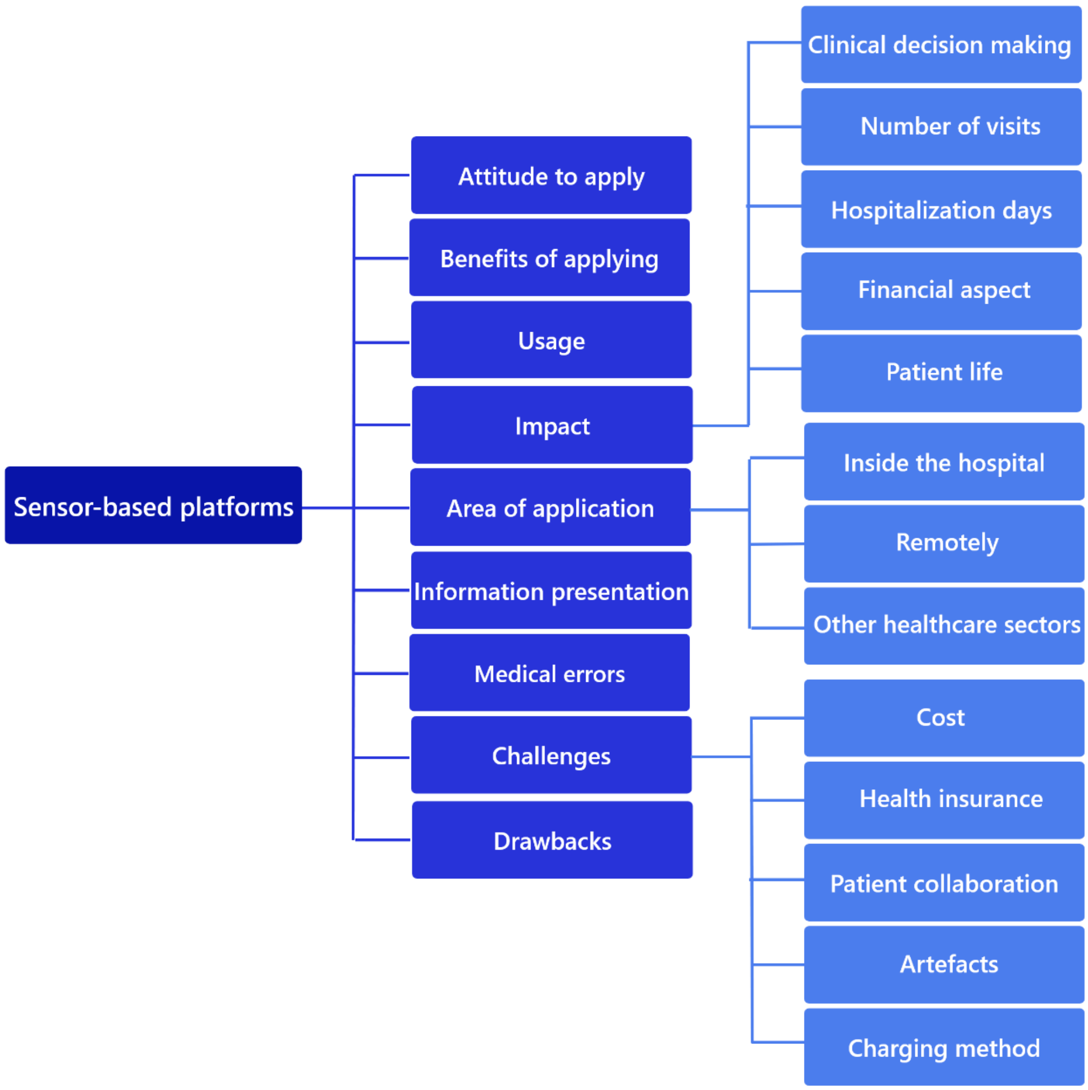


Figure 5.10 Sub-themes of the sensor-based platforms

The detailed information for every sub-theme included in Figure 5.10 is discussed in the next subsections (5.5.8.1 – 5.5.8.9), followed by a summary at the end of this section (5.5.8.10).

5.5.8.1 Attitude to apply

The findings of this interview study on the healthcare professionals' attitudes and perceptions for applying a remote sensor-based device to continuously monitor their chronically ill patients, showed a positive attitude. The participants confirmed that it would be a relief for them to have the patient's history of vital signs and that would also influence the therapies or medication provided, as explained:

> *"Because then you have a patient under monitoring, perhaps even post-operative... when we send home, his/her situation may worsen thus it is good to have such a platform [sensor-based platform], probably it would have been much better." (Interview 3. Doctor)*

> *"It would have a positive impact. You would be able to discover some things that can save us if it would not be monitored." (Interview 12. Doctor)*

> *"It means it is different when you see patient's values all the time, the parameters, and different not to have the monitor at all. It is much better. It is much better to also monitor continuously the patient how he/she is feeling." (Interview 11. Doctor)*

> *"On Monday evening I would read gathered sensor-based data and depending on any patient that will take my attention ... I would contact him/her to come to me the next day." (Interview 24. Doctor)*

Sensor-based platforms may be useful also for diabetic patients, for example:

> *"You would not need to inject the patient, to damage also physically and also make the patient feel mentally uncomfortable. Many patients say "ah I need to get injected to measure this blood sugar" [words of the patients]. If we would have the sensors, it would also improve the quality of life." (Interview 2. Nurse)*

> *"To make as many measurements as it [the sensor-based device] can. To see parameters such as glycolyzed haemoglobin, or even fat." (Interview 15. Doctor)*

The above comments showed the opinions and positive attitudes of various healthcare professionals coming from different departments. However, while discussing the application of the sensor-based platforms, there is also the responsibility of medical personnel to see gathered data and provide feedback. As elaborated in subsection 5.5.7, also here, nurses somehow delegated the responsibility of providing feedback, to doctors, as they indirectly mentioned:

> *"Of course, it seems to be a very good idea (.) to monitor patients outside the hospital. As I told you earlier it is much easier for the doctor to look at the situation, he/she [the patient] has had at home and not just here. It is a great advantage if they are also monitored at home." (Interview 21. Nurse)*

> *"For myself, I'm talking, I would feel very good. Because I would have that belief that even if the patient goes, he/she is under the supervision of the doctor that follows up everything." (Interview 20. Nurse)*

Nevertheless, generally, participants had a positive attitude regarding the application of sensor-based platforms. Moreover, they also confirmed that this type of monitoring would be easy for patients and improve their wellbeing, as explained:

> *"That [sensor-based device] is much better, of course. It's very, very good. Much more effective. It would be also very easy for the patient." (Interview 11. Doctor)*

> *"In my opinion, also the patient feels better and we could see patient's information. Then when the patient goes out of the hospital every change of the ECG, everything. In my opinion it is very good." (Interview 20. Nurse)*

> *"… we would notice an extrasystole or tachycardia and immediately we could inform the doctor and we would react in the patient; we would give them something. This would result positively in the patient." (Interview 17. Nurse)*

"If we assume that they are done well, it would be good because they [sensor-based devices] could prevent many diseases. Or to the deterioration of the patient's condition. They could prevent it." (Interview 19. Nurse)

There were also some other opinions of nurses that seemed not to understand very well the concept of the sensor-based applications, and maybe as they could not see the device physically, they could not imagine how it would be for the patients to wear such a device, for example:

"The patient (..) now I cannot be in the position of a patient. Perhaps that is the solution for the patient. But on the other hand.. now I do not know, how does that look like [the sensor-based platform] does it disturbs in everyday life, at work, in your activities. Its access to our daily routine." (Interview 10. Nurse)

"Just that I do not know how well they would feel to have a device in their body. They might be worried. The fact that they keep it. I do not know for myself [narrows the arms as in doubt]. Maybe it would disturb me. But when it comes to health, why not. Why not keep it for a while." (Interview 19. Nurse)

These opinions may be related to nurses' experience with the existing digital monitoring system. The system had wires and the glue of the electrodes sometimes bothered the patients and did not let them sleep well. These were some of the reasons or drawbacks that were discussed also in subsection 5.5.3.3.

While discussing the idea of remote monitoring through sensor-based applications, the healthcare professionals proposed the system to provide alarms, for example:

"However, if he/she [the patient] has a rhythm disorder or cardiac arrhythmia, it would be helpful to have an alarm. Any signal. Since I cannot sit all the time and see what he/she [the patient] is doing. But to have any signal that tells me that a rhythm disorder has occurred and I look at it immediately. "(Interview 26. Doctor)

"It would be perfect, just that I think that there should be an alarm. To alert us regarding the vital signs." (Interview 19. Nurse)

Or as another doctor proposed to filter patients in need, for example, present patients that have critical conditions first:

"I would filter them to present to me the information I need. Not all the patients. Because you may not need to look at everyone when you have no reason." (Interview 25. Doctor)

The above comments show healthcare professionals' attitudes towards the application of sensor-based remote monitoring and respond to incoming alarms even though that this may take a lot of their time, as described:

"*… but it can take more time. Because you, for example, if a patient is treated here, and now goes home and if the device is placed and you have to check all the time, you should see the parameters, it means (..) it is likely to take more time." (Interview 10. Nurse)*

It is also important to mention that from the 26 interviews, there was a doctor that did not like the idea of remote and continuous patient monitoring. The concern of this doctor had to do with the person who will monitor the patient, as explained:

> *"I come at work; I have the equipment [the digital monitoring system of the hospital] here. When I go home, I close the laptop. I cannot deal to look where did my 1000 or more patients that I have, have gone." (Interview 7. Doctor)*

Hence, this doctor pointed out an important consideration that the managing board of the hospital may decide after having the sensor-based platform and deciding to apply it. Hence, it might be the organizational context to arrange the monitoring personnel that would provide feedback to remote patients, as discussed also during the second interview study (subsection 7.5.6).

5.5.8.2 Benefits of applying

The interview study also investigated healthcare professionals' opinions related to the benefits that remote and continuous monitoring through sensor-based platforms would provide to their chronically ill patients in a developing country, Kosovo. This study's findings on the benefits of applying sensor-based platforms are listed as follows:

- continuous monitoring,

  "We could monitor him/her [the patient] constantly, it means it is better monitored, every change on him/her. Hence, if it is with that device [the sensor-based platform], it is monitored outside the hospital and we are aware of other things." (Interview 20. Nurse)

  "Then you are connected with the patient for 24 hours and whatever happens to him/her it is easier to react." (Interview 14. Doctor)

  "Because if a patient goes out from here, here we constantly monitor him/her, but if something goes wrong and there is a change, we cannot monitor him/her continuously. But if it is with this device [the sensor-based platform], it would be better. For the patient and the medical staff too." (Interview 20. Nurse)

- present the information that healthcare professionals need,

  "It means this device [the sensor-based platform] gives you extraordinary elements." (Interview 26. Doctor)

  "Absolutely [convincingly], it [the sensor-based platform] is the best parameter. Better than the family members to inform you when it happened or what has happened." (Interview 3. Doctor)

  "We can discover unexpected events that at a given moment we do not have them. A cardiac event that we cannot catch here, we catch in the distance." (Interview 12. Doctor)

- history of a patient's condition,

  ".. it would absolutely facilitate [convincingly] the work because you have a basic overview when there has been a distortion of the situation, when the saturation was low, or when there

was a very high blood pressure, for how long, with what was treated that blood pressure." (Interview 3. Doctor)

"Personally (..) I would feel better if, for example, I would have a (..) a list of vital parameters for at least a week." (Interview 9. Nurse)

"For example, to have a history and to look at the blood pressure, to look the time, in the morning it was normal, in the noon normal, but it increased during the evening. Now also for the application of the therapy, we do not assign a medication during breakfast, but during the evening. Hence, you monitor the blood pressure and according to those values, you also give the therapy." (Interview 16. Nurse)

- real-time monitoring,
  "Benefits would be mainly in accessing the information table for the current situation and having this information on the current situation." (Interview 24. Doctor)

- facilitate the work of healthcare professionals,

  "It would facilitate a lot. It would reduce the time to deal with a patient. It would give us more free time, to deal with other things. A psychological relief." (Interview 5. Nurse)

  "However, it facilitates the work. Facilitates the work. And it increases the responsibility of the doctor that if he/she detects the deviation of the vital parameters he/she must intervene. "(Interview 24. Doctor)

- improve patient care,
  "Benefits (.) the patient and the physician, the benefit on time is the first one. It saves time, always. Also, the cost. Cost. The patient's pocket. Another benefit besides time is transportation. Since the patient does not need to come here." (Interview 18. Doctor)

  "I mentioned earlier that of course, the patient benefits a lot if he/she is also monitored outside the clinic. This is because (.) he/she may have a much better situation if proper therapy is applied. There may be fewer complications because it is known that there may be serious complications if a disease is not treated. "(Interview 21. Nurse)

In general, the healthcare professionals perceived the benefits of sensor-based platforms to be mutual, for the patient, to improve his/her wellbeing, and the medical personnel to facilitate their work and improve clinical decision making.

5.5.8.3 Usage

Seen the attitudes and the benefits of the sensor-based platforms, this study further investigated the practical implementation or the usage of such applications for remote and continuous monitoring. Hence, in this context, the healthcare professionals confirmed that even if the patient would hesitate, they could explain that it is for his/her wellbeing, and in that case, the patient might accept. Of course, these opinions are based on healthcare professionals' experiences with the already implemented digital monitoring systems. Hence, they thought that if the patient is conscious and if the healthcare professionals will explain the advantages of remote and continuous monitoring, they would accept them, as explained:

"… we have many cases here, even if the patient hesitates if you attempt to explain that it is for his/her good (.) I believe he/she will accept. If explained properly. "(Interview 10. Nurse)

"When a patient is diagnosed with a disease, he/she has a kind of concern and always asks for a solution. And if you sit down and explain to the patient that this device would help for this, and this .. the patient would accept it very easily. I am sure that they would accept it, very easily." (Interview 2. Nurse)

"… of course, patients are worried about their condition and if we tell them about their condition, the benefits that these [sensor-based platforms] bring, of course, they will listen to us. "(Interview 21. Nurse)

"That yes because it is the same as we suggested to the use of the therapy. We can similarly suggest these devices [sensor-based platforms]. It also means that in Holter's device we have suggested. "(Interview 14. Doctor)

"And the patients obey more on doctor's words. "(Interview 20. Nurse)

Nevertheless, the healthcare professionals can advise and suggest the application of the sensor-based platforms, however, the patients need to decide on their own, as explained:

"I believe we can convince them. Now you cannot convince everyone. You cannot have the effectiveness in everyone but on the majority, yes. "(Interview 25. Doctor)

"We have as an obligation, for example, to explain the positive and negative sides. He/she decides afterward. "(Interview 23. Nurse)

"The aspect of patients remains individual. "(Interview 24. Doctor)

Some healthcare professionals also discussed the mistrust of patients in doctors' words. These healthcare professionals mentioned that previously it was easier to talk with a patient and advise them because they were obeying easily, but now:

"… it is that impression that it was only for money [when doctors advise something to patients]. They are in a dilemma [patients]. "(Interview 5. Nurse)

"Now it's useless if you tell them to do this or that because they only think about issues, they think the doctors are doing it for material matters." (Interview 26. Doctor)

From these comments it is concluded that it is an individual matter of the doctor, to explain the benefits of using sensor-based platforms and patients, on the other hand, to believe in the advantages of sensor-based applications and use them. There were also healthcare professionals that could not comment on this because as they said they need to see the device first, for example:

"Let it get on the market first, then we see." (Interview 12. Doctor)

"Whilst we do not know (.) I cannot see how it looks like [the sensor-based application]. So far I have not been informed that such an application can exist." (Interview 10. Nurse)

This subsection presented the findings of this interview study on the usage, or proposal of the sensor-based platforms for application by chronically ill patients. The following subsection will discuss more in detail the impact of such applications in various aspects of clinical usage and practical implementation.

5.5.8.4 Impact

This subsection discusses the impact of the sensor-based platforms on clinical decision making, the financial aspect of patients, patient's life, number of visits, and hospitalization days, as presented in Figure 5.11.

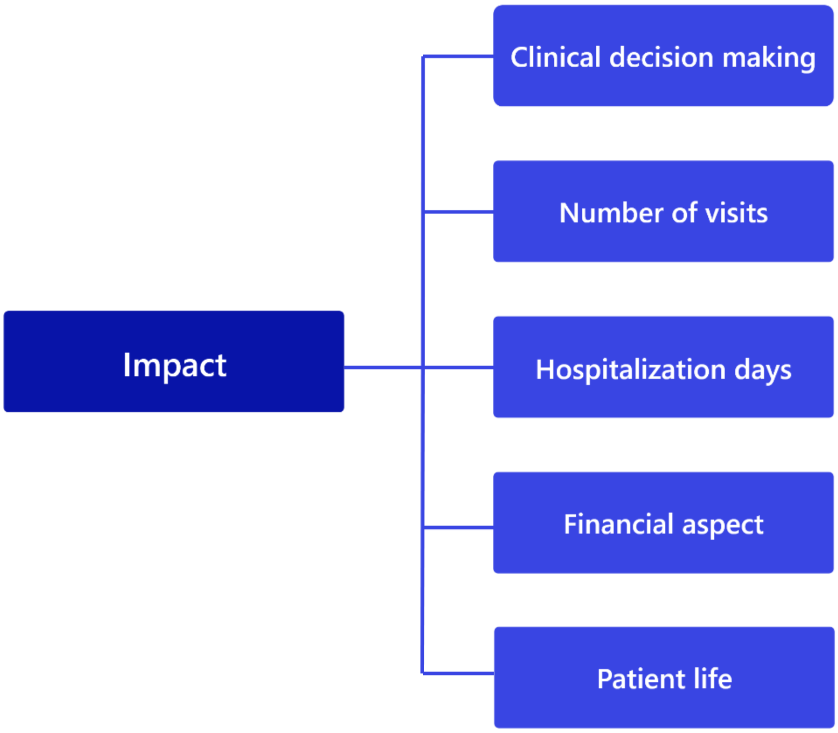


Figure 5.11 Sub-themes of the impact of sensor-based applications

The emerging sub-themes presented in Figure 5.11, are elaborated in the following paragraphs below.

Underlying sub-theme 1: Clinical decision making

The healthcare professionals talked about the impact of the sensor-based applications in their clinical decision-making. Hence, a report of measurements for a specific interval of time, or critical values of the vital signs and their implication, would facilitate the application of specific therapies and help the medical staff to control and monitor their dose and how it is reacting. This also considering that they are dealing with chronic parameters and their values fluctuate very often and depend on many factors, as a doctor also pointed:

> *"For example, it is different if you monitor a patient every moment. And is different when he/she [the patient] comes once in two months and shows a current ECG and current blood pressure. You do not know how it [the ECG] was last night or earlier." (Interview 25. Doctor)*
>
> *"It informs the doctor directly so that he/she can make the changes in the therapy. "(Interview 1. Nurse)*

"You see how a drug or medication has affected. Are they stopping the arrhythmia, or aren't they?" (Interview 14. Doctor)

"Because I want to know if the patient has two pills with the same mechanism of action, but with different doses, now depending on their pharmacodynamics and pharmacokinetics, I want to know in which patients, one or the other pill, has the best effect." (Interview 24. Doctor)

"Because if I find a corresponding atrial fibrillation on a patient then I will not give an aspirin but other coagulation that would protect much more than the aspirin would." (Interview 4. Doctor)

These opinions confirmed the benefits of having a history or a report of a patient's vital signs for a specific interval of time. This was identified and listed as a benefit of sensor-based platforms also in subsection 5.5.8.2.

Underlying sub-theme 2: Number of visits

The remote and continuous monitoring of chronic patients can affect their number of visits to healthcare centres. Therefore, the findings of this study showed a diversity of healthcare professionals' opinions in this regard. There was a group of participants who thought that the application of sensor-based platforms would increase the number of visits in the hospital, and the other group that thought it would decrease.

Considering a patient's background or the level of education regarding their diseases, a group of healthcare professionals mentioned that the application of sensor-based platforms for remote monitoring would increase the number of visits to the hospital. They perceived that a patient seeing his/her condition, or values of the vital signs, may worry and visit the healthcare centre more often, for example:

"I think that the number of visits would be higher. "(Interview 10. Nurse)

"It would increase, as people in every alarm will come and visit the doctor. "(Interview 3. Doctor)

Another reason for the increased number of visits would be the early diagnosis of chronic conditions, or as the doctors said:

"Perhaps there would be an increased number of patients. Since I told you that they are unaware that they are sick of heart. "(Interview 26. Doctor)

"To increase the interest. And in the long term even to lower the prevalence level, if this will be used also for early screening (..) the number of diabetic patients' visits can increase, but the control will get improved a lot. Because nearly half of diabetics are not diagnosed. "(Interview 15. Doctor)

The other group of healthcare professionals perceived that the number of visits that chronically ill patients will make in healthcare centres if they will use a sensor-based device will be lower compared to the current trends. They said that this number will be decreased as the patient will visit the doctor only in emergencies or when the doctor advises them to come. Moreover, healthcare professionals said that they would redirect or provide assistance from a distance which further supports the conclusions of subsection 5.5.8.1 on the positive attitudes, as explained:

“I believe that would reduce the number of visits in the clinic. “(Interview 12. Doctor)

“We could redirect him/her [the patient] from distance, and he/she would not have the need to come, and if the patient were to come for a certain date, we could say that he/she may not come because everything is fine. “(Interview 25. Doctor)

“In reality, the number of visits will get decrease. “(Interview 14. Doctor)

“There will be fewer visits. “(Interview 18. Doctor)

“They would get reduced. Everyone would be checked from their house. “(Interview 22. Nurse)

However, considering that the interviews were conducted in a private healthcare centre, some participants also expressed their concerns regarding the reduced number of visits as they get some earnings also from that, for example:

“Individual matter of each physician. “(Interview 24. Doctor)

In general, it is concluded that the number of visits may depend on some factors such as the variety of the population that will wear sensor-based applications, patients’ education about their chronic disease, and healthcare professionals’ willingness to provide feedback.

Underlying sub-theme 3: Hospitalization days

Besides the number of visits, this interview study also investigated the hospitalization days of the patients with chronic diseases if they were already using a sensor-based application to monitor their health status. The healthcare professionals confirmed that the application of sensor-based platforms can impact the number of hospitalization days, for example:

“I believe that [the sensor-based application] would shorten the time of hospitalizations. It would prevent unnecessary hospitalizations. In both sectors [public hospital and private ones]. “(Interview 12. Doctor)

“It will affect automatically. Because the patient is being monitored and you can see the situation and it does not come to the deterioration. “(Interview 18. Doctor)

“I believe that the number of visits or hospitalizations would be limited [would decrease]. Because if good monitoring is done then the patient will also have a good condition. So, there will be no need to come to the hospitalization. “(Interview 21. Nurse)

Underlying sub-theme 4: Financial aspect

The findings of this interview study revealed the impact of the sensor-based applications on the treatment costs of chronic diseases. As participants also confirmed, the treatment cost was a factor closely related to the number of visits or hospitalizations:

“The costs I believe that (..) I do not believe that it will increase the costs. Because if you stop the visits then you pay this instead of paying the visit. “(Interview 12. Doctor)

“Of course, it will lower them. Because if the number of visits is lower, spending will be less. Even though I do not know the price of the device but I believe that it would reduce the costs. If the visits are less frequent. “(Interview 21. Nurse)

“Maybe in some cases, it costs less. Because it prevents frequent hospitalization of the patient. And hospitalizations cost a lot. Or when it prevents a stroke when you see it has the biochemical parameters that send to chemical disease, it is much easier and cheaper than to start and apply therapy. Or different interventions that cost more. “(Interview 26. Doctor)

“... every visit has its costs; every visit has new therapies or various tests so (.) in short words it would decrease the family cost. “(Interview 9. Nurse)

The financial aspect of applying sensor-based platforms is extremely important especially for developing countries, such as Kosovo. This was also mentioned by participants that said:

“Because you know that in Kosovo the unemployment is very emphasized, and then (..) for the therapy or a night that the patient stays here [in the private clinic], probably for a person with a normal salary, it is much more expensive here, so it is more difficult for the patients. “(Interview 11. Doctor)

Some healthcare professionals perceived the decrease of the cost of treating chronic diseases in longer terms, or as they declared:

“Initially it appears to be more expensive [when buying the sensor-based device] but it may lower in the long term. “(Interview 15. Doctor)

“In the long term Yes [convinced] there is such a possibility. “(Interview 6. Doctor)

“I think that would reduce the cost of ongoing expenses. Many patients visit the doctor only for blood pressure or glycaemia. These that are in family centres have a very low cost of visits. They pay only €1 or €2. However, if they every day, or every week, spend €1 or €2, then it would again be a high cost if you look at the end of the year. Hence, you spend once to buy it, but you would not have to spend constantly for it. “(Interview 17. Nurse)

These comments are related to the idea that the patient will spend once when they buy the sensor-based platform and then they will get its benefits while using it. However, without knowing the real price of the sensor-based platform some healthcare professionals had difficulties in discussing regarding financial aspect. Some of them even thought that the cost of the platform would be equivalent to the cost of visits, or:

“... and that [the sensor-based application] is probably more costly, I think it's easier to come and do a check-up for €20, see the doctor than to buy it. Although maybe (.) someone visits more often and becomes the same as buying it. It's the same cost as the visits. “(Interview 22. Nurse)

While some other healthcare professionals assumed that the sensor-based device will cost a lot, for example:

“Yes, for that I said the price. Now I do not know how much it [the sensor-based device] will cost. But it would certainly cost a lot. “(Interview 25. Doctor)

“Yes, yes, but I believe that the specific device cannot be used by every patient. Because that device costs (..) and as I see, as the situation in Kosovo is, everyone cannot use it. “(Interview 8. Nurse)

Consequently, the cost of the sensor-based platform presents one of the key factors that may determine the successful implementation of such remote and continuous monitoring especially in a developing country such as Kosovo.

Underlying sub-theme 5: Patient life

The participants of the interview study confirmed the impact of the sensor-based platforms on a chronically ill patient's life. They discussed how the remote and continuous monitoring through a sensor-based device would affect a patient on the following aspects:

- provide better treatment,
  “...the patient is diagnosed and cured properly. “(Interview 12. Doctor)

  “It can increase the quality of healthcare services delivered to the patient. “(Interview 6. Doctor)

- be informed about his/her health condition,
  “Gets informed about the values he/she should have. He/she has an overview of his/her condition and can start and manage himself/herself. He/she can know when to visit the doctor and when he/she may not. I believe that the patient will become even more conscious.” (Interview 21. Nurse)

- saves time,
  “It shortens the time to go to the doctor [laughs]. Long waits at the doctor. Making appointments with the doctor. It shortens many things for chronic patients. I mean there is no need to go too often to the doctor. Transportation costs. Patient time and doctor time- if there are also other patients. Absence from work, you should get permission [laughs].” (Interview 1. Nurse)

  “Yes, it will reduce the time that today has become very valuable. When you will say to the patient you do not need to come just send me the report, this tells me if you're good or not, if you have any concerns or not... the patient will accept it all excited.” (Interview 2. Nurse)

- enhance the quality of life,
  “...because chronically ill patients visit the doctor very often... and when know that they have a device that the doctor can see directly and they do not need to wait or do not need to go ... of course, it enhances the quality of life. It returns the patient in very normal life.” (Interview 2. Nurse)

  “For example, patients who have received relevant pill when they had rhythm disorder, were 70% protected from stroke; those who did not were 30 or 40% protected. It means you are giving 70% fewer changes to the patient to have an attack, compared to when not used and

he/she had 40% changes ... because the difference is double. It is therefore a direct intervention in the patient's quality of life. "(Interview 4. Doctor)

"They would increase the quality. They increase the longevity. "(Interview 15. Doctor)

"For them let's say there is not a high improvement, because we know that chronic diseases just go on and continue until the last stage of the life; but it will increase the quality of life. "(Interview 19. Nurse)

- reduce the number of deaths,
  "A lot (.) a lot of chronic diseases can send even to early death. And I think that this number would get reduced (..) as cardiac arrests, such as hypertension, diseases of sugar that are coming to the amputation of limbs, these all. I believe it would affect the reduction of the number of deaths. "(Interview 10. Nurse)

Besides these aspects which all provide benefits for the patient, the healthcare professionals discussed also the impact of sensor-based platforms on the psychological aspects of a patient. Hence, they elaborated the possibility of creating concerns for the patients, as follows:

"Now is the psychological aspect. Because when people do not understand these things, every alert of that application can bother the patient. And may create concern. "(Interview 3. Doctor)

"Because for example, patients who do not know the health conditions, or similar (.) they take things more stressful. And can make panic and it is worse. "(Interview 8. Nurse)

Hence, considering all the listed aspects, it is concluded that these factors depend also on a patient's body, knowledge about the disease, and the financial situation.

5.5.8.5 Area of application

Even though this research study aims to present the architecture of a remote monitoring sensor-based platform for chronically ill patients, some of the participants proposed the application of such platforms also inside the hospital, or for other healthcare areas. Hence, as shown in Figure 5.12, this subsection will discuss the three underlying sub-themes related to the area of application of the sensor-based platforms for a healthcare setting.

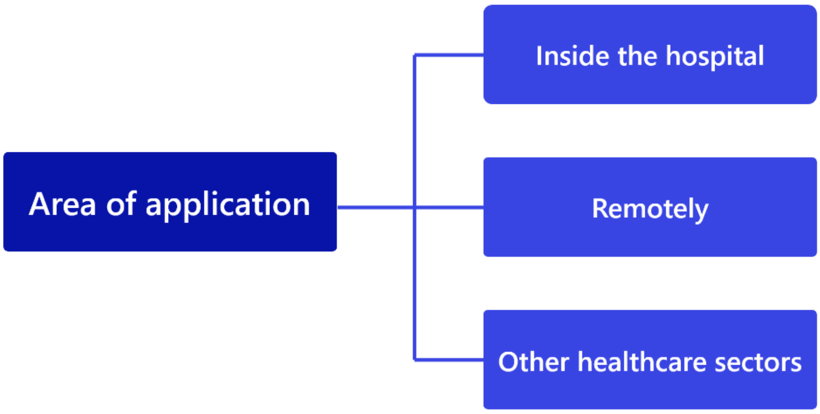


Figure 5.12 Sub-themes of the area of application for sensor-based platforms

The following paragraphs provide details of the underlying sub-themes presented in Figure 5.12.

Underlying sub-theme 1: Inside the hospital

The digital system that the hospital was using to monitor their hospitalized patients, had wires that were somehow binding the patient with the bed. The patient was not free to move. In this context, while presenting the idea of the sensor-based architecture, they thought that this platform could be applied also within the hospital, for example:

> *"I do not know (..) because if this is applied also for the clinic it is probably a good solution. It is not only for the distance." (Interview 10. Nurse)*

> *"The annoying things are wires since the patients are tied to the bed. So, it would be good for the patient to have the device and move freely." (Interview 2. Nurse)*

> *"There are times when the patients are uncontrolled in one aspect that are more aggressive. And instead of removing the cables, this [the sensor-based device] it is more isolated and makes your job easier." (Interview 5. Nurse)*

The application of sensor-based platforms for hospitalized patients would help also the public healthcare centre, as suggested by a participant:

> *"I think that for a clinic [public hospital] it would be a must. Especially for guard teams. Because if I am a caretaker in the clinic, I do not care only about the coronary unit but also for two other units. And now if most of the time I would have patient's records when I am currently consulting or examining another patient, in another clinic within the UCCK, then you see what priority it is." (Interview 24. Doctor)*

Underlying sub-theme 2: Remotely

Besides the fact that participants were suggesting to apply the sensor-based platforms inside the hospital, they agreed that the designation of these platforms was for remote and continuous monitoring of their patients. Hence, healthcare professionals see more benefits from the usage of sensor-based platforms outside the clinic or as they suggested:

> *"For Kosovo, it is more needed outside. On the inside you can do even with the cables it is not a problem." (Interview 14. Doctor)*

> *"Well, inside the clinics we have these monitors [digital monitoring system] (.) perhaps that would be good, but as we have these monitors, we would not need them. We would need them more for the outside." (Interview 17. Nurse)*

> *"But I believe it would be more important in patients who are at a distance. Rather than for patients who are in the hospital." (Interview 26. Doctor)*

> *"No, I think that we can use also here, but I believe the intention is to be used at home." (Interview 4. Doctor)*

The above comments suggest that the sensor-based platforms would be more needed at a distance as within the hospital they already have their digital monitoring system.

Underlying sub-theme 3: Other healthcare sectors

While discussing the idea of sensor-based platforms with the healthcare professionals, some of them even mentioned other healthcare areas for the application, that were different from chronic diseases, for example:

- Brain stroke
  "At the age of 80, every fourth brain stroke is caused by fibrillation, meaning 25%.. I have many patients that I believe the brain stroke is with aetiology from heart- rhythm disorder, but cannot prove it." (Interview 4. Doctor)

  "There are cases, for example, neurologists, it is patient of doctor X, but it also has problems with heart. Now also a patient that is my relative has had a brain stroke. And during the examination, it was noted that the complication of the heart has caused the brain stroke." (Interview 5. Nurse)

- Acceleration of the blood flow
  "*… for us, it is very important to monitor the blood flow in blood vessels in the neck. So, it would be very good, if there is a way or a method that enables measurement of the speed of blood flow in the neck. It means we have two main arteries in the front part of the neck and two in the back part of the neck. And a method, for example, any sensor or any patch, that would allow us to know how fast the blood circulation is or how slow it is. This is because what interests me is that blood vessel is like a tube [it demonstrates through a pen] then often this tube is blocked from thrombus. And for example, when the blood vessel is blocked, there is a narrowing or stenosis. And if this bottleneck is above 50 or 70%, then the blood will have difficulty passing through it as it is a narrow part, so it will be accelerated. So, it needs greater pressure for the flow to be faster at that level. Therefore, this speed will indirectly give us information that there probably is a barrier for the blood to flow, thus by knowing the barrier it grants us an opportunity to prevent a brain stroke, because we may make surgery and take-off it, the tromp, that is narrowing the blood vessel." (Interview 4. Doctor)*

- Epileptic activity
  "Patients who have problems with epilepsy. I do not know if this [the sensor-based platform] measures these reactions. Head ... before the start of the attack, how the patient reacts. What signs it gives. How does the body changes, what are the changes in the vital signs before the start of the attack?" (Interview 1. Nurse)

  "Something else that we can monitor from distance is also the epileptic activity." (Interview 4. Doctor)

Therefore, it is evident that the healthcare professionals noticed the benefits of sensor-based platforms and were proposing also other healthcare areas where they could help them by providing information. Further to this, the information presentation concerns another important aspect for viewing and accessing a patient's vital signs. Hence, the following subsection provides details on the methods suggested for data presentation.

5.5.8.6 Information presentation

Before proposing a sensor-based platform, this study aimed to investigate also healthcare professionals' suggestions on how to visualize or group the gathered sensor-based data, to be easier for them to read the information (patient's vital signs) and provide feedback. Hence, participants discussed the presentation of the patient's vital signs in terms of graphs, tables, or numerical values. Most of them agreed that the changes of the ECG should be presented through graphs, and the numerical values in the table form including also the time interval when they were measured, for example:

> *"Well, you cannot display ECG in a table. Because ECG is ECG it should be seen as a system, as a picture. While the blood pressure can be also in a graph form." (Interview 14. Doctor)*
>
> *"Even with graphs, it is extra [means special]." (Interview 15. Doctor)*
>
> *"Perhaps simpler would be in the form of graphs." (Interview 19. Nurse)*
>
> *"I think that the values would be tabular or whatever. But those comparatives could be visualized through graphs. Graphs (.) gives a slightly more visual impression, more effective." (Interview 24. Doctor)*
>
> *"Now in the tabular form or the form of a curve, it would be easier." (Interview 25. Doctor)*
>
> *"Perhaps in the form of the table. Of course, the blood pressure, pulse, and the time interval when he/she measured." (Interview 16. Nurse)*
>
> *"In the form of tables I would say. Easier." (Interview 20. Nurse)*
>
> *"Graphs help a lot. For example, it is compared when there was the highest blood pressure when there was the lowest blood pressure through the graphics." (Interview 21. Nurse)*

Healthcare professionals even saw this as a minor thing as they just wanted values to get displayed to them, for example:

> *"No matter, just to give me a tip of what is happening." (Interview 4. Doctor)*
>
> *"That does not matter, every format can be evaluated on its concept. It does not matter.. even with numbers, with graphics and tables.. those formats are technically transferred from one to another." (Interview 6. Doctor)*

Generally, healthcare professionals preferred a simple and readable form of presentation regarding sensor-based data that represent a patient's vital signs. Graphs and tables were mentioned mainly as the best presentation format of the gathered data from patients.

5.5.8.7 Medical errors

The healthcare professionals raised some concerns about the data accuracy of the gathered information from the sensor-based platforms. Hence, this subsection presents the findings on possible medical errors that may be caused by inaccurate data. In this regard, the healthcare professionals considering their experience with the digital monitoring systems confirmed that in cases when the devices display critical values and they see the patient condition to be fine, they measure again the vital signs or use manual devices to measure them, as explained:

> *"To tell you the truth when we see a (.), for example, high blood pressure value or something, we measure again with the manual one, with cuff. Simply to make the difference because it happens that the device has sometimes a disbalance. They cannot always be very, very accurate." (Interview 11. Doctor)*

Considering their experiences, participants confirmed that there might be mistakes due to incorrect values displayed by the sensor-based device, as follows:

> *"Just in case that it presents incorrect values. Then there may be errors." (Interview 16. Nurse)*

> *"If they would not show real values of course that there will be mistakes. And they would be fatal. So, they have to be very reliable devices." (Interview 19. Nurse)*

> *"If the values of the device would be unrealistic, then incorrect measures can be taken towards the patient." (Interview 9. Nurse)*

According to healthcare professionals, some possible reasons why medical errors may happen are:

- Sensitivity of the device
  "All depends on the sensitivity of it [the device]. How you manage to convince the doctor with the evidence that this is okay. Then the doctor's mistakes may be related to the values shown." (Interview 15. Doctor)

- Not adequate placement of the device
  "Well, there may be mistakes if the patient has not set properly the device and based on that, we from the distance, we do not know how he/she [the patient] holds it and we see a value for which we may give a therapy or something, and no matter how simple it is, it could be wrong." (Interview 17. Nurse)

In this way, healthcare professionals suggested that they should not rely only on the displayed values, but also on other parameters and tests to come up with a decision, for example:

> "*Because no doctor is always right or not always the patient is right. Those parameters (.) based on them you decide on the therapy. And it is not that you make a mistake. Because that was displayed. Same as in the monitoring system [that the hospital uses]. Unless he/she is not careful to request additional parameters that apply to that disease." (Interview 18. Doctor)*

> *"Because if you are going to rely solely on what these [sensor-based applications], without making any connection let's say between biochemical tests, then these imaging ones, for example, the ECG, and these." (Interview 26. Doctor)*

> *"We have experience for their application and we try to verify them several times before we confirm a result concerning these parameters." (Interview 6. Doctor)*

The findings of this study show that there is a possibility for medical errors due to the accuracy of the sensor data that are presented to medical personnel, considering that the patient is at a distance and the healthcare professionals cannot see his/her condition. However, as healthcare professionals suggested, in these cases, some factors should be considered, such as the device placement, the history of other parameters or tests, and data communication infrastructure.

The data accuracy may lead to possible artefacts or wrong clinical decision-making. This is considered as one of the challenges for the successful implementation of sensor-based platforms, as presented in the following subsection.

5.5.8.8 Challenges

Challenges that should be considered before proposing a sensor-based architecture are closely related to the factors presented in the previous subsection. Nevertheless, Figure 5.13, summarized all the findings related to possible challenges for successful implementation of the sensor-based platforms in the healthcare setting of a developing country, Kosovo.

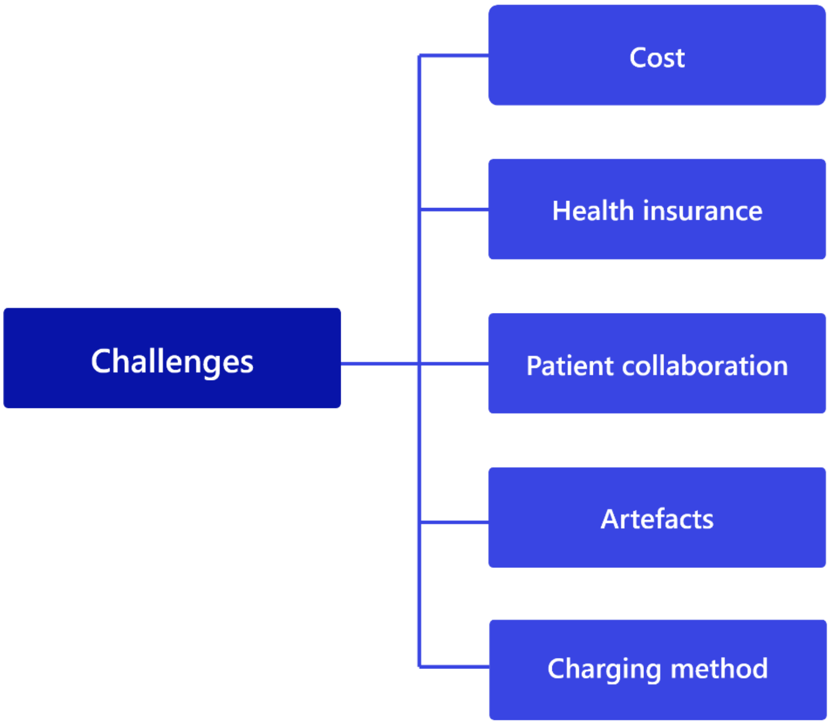


Figure 5.13 Sub-themes of the challenges of applying sensor-based platforms in the healthcare

The sub-themes presented in Figure 5.13 are elaborated in detail through the following subsections.

Underlying sub-theme 1: Cost

The healthcare professionals declared that taking into account the current economic situation of Kosovo, it is very important to consider cost as a key factor for enabling patients to have a sensor-based device. Hence, participants assumed that such a platform may cost a lot and that for a developing country this can be a challenge, as explained:

> *“The financial aspect. This is the first that can prevent. Cost.” (Interview 15. Doctor)*

> *“I did not get interested how much these devices cost outside the country... but the cost can be a limiting reason for this.” (Interview 4. Doctor)*

> *“I think the cost. I see the risk there.” (Interview 1. Nurse)*

"The financial aspect." (Interview 3. Doctor)

"Only the economic issue. I mean, I believe they would cost a lot." (Interview 26. Doctor)

"..yes, it depends on the cost. Because these devices are.. they are very expensive [Drager monitors]. But I guess the other one [the sensor-based platform], I think it is even more expensive." (Interview 11. Doctor)

"The cost of the product I think could be a problem. Because if it's too expensive probably many patients will not buy it because they cannot afford." (Interview 17. Nurse)

In this context, participants suggested that probably the Ministry of Health or other relevant institutions can help in the financial aspect the chronically ill patients to have a sensor-based platform, for example:

"The cost can be covered perhaps with the help of some relevant institutions... maybe they can." (Interview 4. Doctor)

The financial aspect of getting better treatment for developing countries is closely related also with the lack of public health insurance. This was identified as another challenge and is presented as follows.

Underlying sub-theme 2: Health insurance

The lack of health insurance remains one of the main concerns for using health services in Kosovo. The participants of this study were discussing many cases when patients needed to leave the hospital due to financial obligations and lack of health insurance, especially considering private healthcare centres:

"Now, we talked earlier also for insurance, but most of the people come to the hospital if they have health insurance. Because the private hospital is quite different. You have to pay for accommodation, the therapy, the surgery, all." (Interview 10 Nurse)

"If you do not have health insurance, many things remain behind. You cannot apply some things as you wish." (Interview 1. Nurse)

"I believe that would be the economic cost and it will be (.) the health education, lack of health insurance, etc." (Interview 12. Doctor)

According to healthcare professionals, the lack of national health insurance presents another challenge towards the successful implementation of sensor-based platforms in a developing country such as Kosovo.

Underlying sub-theme 3: Patient collaboration

The healthcare professionals considering their experience with the existing digital monitoring system discussed the patient collaboration or their acceptance to use sensor-based platforms. This presents a very important factor that can seriously affect the application of sensor-based monitoring, as explained:

"The other side will be how much the patients will collaborate. They do not visit often the doctor. So, how much are they willing to collaborate." (Interview 1. Nurse)

“And it means also the patient's consent. Or acceptance by patients.” (Interview 25. Doctor)

“It's all about the price, and (.) depends on the person. If approved [by the patient].” (Interview 10 Nurse)

“Then the issue of the autonomy of each patient. Whether they want to carry it or not.” (Interview 24. Doctor)

“.. of course, there is the collaboration with patients, first.” (Interview 4. Doctor)

However, medical staff perceived that patients’ acceptance and collaboration depended also on their knowledge about the device and the method of how to use it. Moreover, in this context healthcare professionals’ advice and suggestions could help them to apply sensor-based devices, for example:

“And it depends on how much the patient has access, knowledge about this. But in the meantime, every doctor contributes by giving information to the patient, by preparing, by learning how to work.” (Interview 14. Doctor)

“Even if I have a complaint from a patient, or any rejection, at the moment that I talked with the patient, the patient accepted.” (Interview 2. Nurse)

In this way, according to healthcare professionals, the sensor-based device should be easy to use, measure accurately the vital signs, and be easy to carry, so that it would be comfortable for the patient and would affect also their adoption:

“And for this, I am very sure that if it is very easy to use, to measure, the patient will accept. Because the patient considers his/her health, considers himself/herself (..) and will accept it.” (Interview 2. Nurse)

“So if it would be in the form of a hand watch, or like a patch it means that you attach to hand.. I believe that would be much more acceptable to patients than would be Holter that is wired.” (Interview 4. Doctor)

The information presented here and these suggestions are considered during the design phase of the sensor-based architecture that is briefly presented in the next chapter 6.

Underlying sub-theme 4: Artefacts

Artefacts were discussed by healthcare professionals as a phenomenon that they encountered in their digital monitoring system and Holter monitors. The digital monitoring system gave alarms when for example the patient moved or changed his/her position and one of the electrodes got removed, this is called an artefact. These were encountered also during remote monitoring performed by Holter monitors. The participants confirmed that they identified these artefacts by comparing the ECG graphs and the values of vital signs after reading the recording of the Holter. Hence, the healthcare professionals mentioned patient movement or not appropriate settlement of the device to be some of the reasons that cause artefacts, for example:

“Perhaps a hand motion.. because we are seeing in Holter for example.. because there are many artefacts. The Holter has the mechanism to dye it with red colour for example when there is a rhythm disorder, and when you open it there are many red-s and notes.. most emerge

that are non-full disorders that make sense, there are more artefacts that the patient has moved or the electrodes moved or something has happened." (Interview 4. Doctor)

"Because, as I pointed out earlier, it is very important that (.) patients who have a digital tensiometer, and if the hand is not in the right position, it does not record the blood pressure well. So, we can get confused and get the wrong values." (Interview 21. Nurse)

"The other thing is that patients may not know how to measure the values of the vital signs. Because every move, every move of the hand deviates." (Interview 25. Doctor)

Hence, healthcare professionals mentioned the hand position while measuring heart rate or blood pressure, or device settlement, or the position of the device, which may cause artefacts, or not accurate values of the vital signs.

Underlying sub-theme 5: Charging method

Another identified challenge was related to the charging method. Batteries affect user acceptance, the performance of the device, and healthcare professionals' belief in such platforms. As healthcare professionals declared:

"For example, blood pressure devices, these digital, I had the opportunity, but with batteries. Once the batteries are getting weaker, they did not measure the same. The blood pressure was not accurate... But it should have a way that the battery lasts longer." (Interview 5. Nurse)

"Because when they [devices] are with the battery it affects also the battery power. And I do not know how accurate these values are." (Interview 9. Nurse)

"I now have a problem, or not a problem, but most frequently that the patients tell us that measure the arterial blood pressure with some devices that are with battery. Now I do not know why, but most of the doctors, but I too, do not trust them very much (.) although in Europe they are used a lot, but to us, they did not show much accuracy because either the battery was weaker." (Interview 25. Doctor)

These participants' impressions are related to various digital devices that were used by patients, and according to them when their batteries were not fully charged, the platforms did not measure accurately. As discussed previously in subsection 5.5.8.7 various medical errors may be caused in these cases when there are data accuracy issues. Further details on other drawbacks that healthcare professionals perceived the sensor-based platforms may have, are presented in the next subsection.

5.5.8.9 Drawbacks

The healthcare professionals agreed on the benefits of using sensor-based monitoring also when they were asked for possible drawbacks, for example:

"I think that in most of the cases patients should have this." (Interview 11. Doctor)

"I do not see any drawback. I only see a very great benefit of the patient and a very high self-confidence in him/her. Because while a patient goes out on the street, something can happen to him. So, if you have that [device] you feel more confident." (Interview 20. Nurse)

However, not all healthcare professionals thought the same. Some participants expressed their concerns related to the continuous monitoring, as they thought it might be stressful or that may cause concerns to patients who use it. For example:

> *"With 24 and 48 hours Holter I have seen the patients.. maybe the fact that they had a device placed in the body, I can say that they were very concerned. – I do not know how it will turn out, it would turn up any disease, if I will damage it, is it measuring well- [patients' words]." (Interview 21. Nurse)*

> *"Maybe keeping the device all the time. To take care of that device. It's uncomfortable. Same as the watch or the phone.. when you have it you think that it will display all of your health, and you tend to be careful not to damage all the time and this is a burden." (Interview 2. Nurse)*

> *"Patient's thinking that is always monitored and it feels the problem to even get dressed." (Interview 25. Doctor)*

> "*I think it might feel stressed. Maybe it's a bit stressful to be all the time connected with a device." (Interview 21. Nurse)*

Hence, some healthcare professionals proposed not to use the sensor-based platform all the time, but only when the patient would not feel good or as they mentioned:

> *"It is worrying that it is monitored all the time. It's worrying for the patient. I do not think it's a good idea. I would suggest that not [use it] all the time. Because then it means something (.) the patient thinks that something is not good as he/she is using it all the time." (Interview 23. Nurse)*

The number of visits was mentioned as one of the impacts that sensor-based platforms could have on the healthcare setting. Moreover, considering a private hospital and the lack of health insurance, the number of visits would directly affect the financial aspect of the institution where the sensor-based platforms could be applied. In this context, a doctor that thought the application of SBN would decrease the number of visits raised the concerns as follows:

> *"Because in a hospital such as the American hospital, to patients without health insurance I do not know how it would be accessible and acceptable for them to advise the patients because the incomes of the hospital would decrease. This is good for the state and the patient, but for many hospitals, it would be counter-productive." (Interview 12. Doctor)*

The cost of the device, besides being a challenge was considered a drawback also. Doctors' perceptions regarding sensor-based platforms were that they were very expensive. And this was seen as a drawback based on doctors' experience or as explained:

> *"And this [GCM] is very good if it was cheaper, everyone could have it. We had a list of patients that were coming, but when they were informed about the price, they could not do it, they could not put the device. Because the insurance does not cover it." (Interview 15. Doctor)*

These were some of the opinions of healthcare professionals based on their experience with the existing digital technologies applied in their hospital. However, as they confirmed, they are not using any real-time and remote monitoring:

"I cannot say as until now I have no experience. Since I have no experience, I do not want to prejudge." (Interview 24. Doctor)

"I do not know about it now. I'm talking according to phones, or studies that are saying that they have their impacts, it means negative. But so far, nothing concrete has emerged. Just assumptions. I do not see, I told you again, l see much more positive sides than negative." (Interview 26. Doctor)

"No, we do not have such applications to tell you about the drawbacks." (Interview 6. Doctor)

Nevertheless, even the current experience and the healthcare professionals' suggestions based on that, provide valuable feedback for this study to consider before proposing the sensor-based platform.

5.5.8.10 Summary

The findings on the theme of the sensor-based platform showed that healthcare professionals had experience in remote monitoring using some wired sensor-based devices. However, either when using Holter monitors, or CGM, they could only collect a patient's data at a distance, but they did not have access to those data until the patient came back to the hospital and brought the device. Nevertheless, this helped to discuss more in detail regarding sensor-based platforms, considering that participants had an idea of these technologies.

In general, while investigating healthcare professionals' attitudes, it was concluded that they had a positive attitude to remote and continuous monitoring of their patients. They perceived that this kind of monitoring would even help them in writing therapies, medications, or managing their patients. Furthermore, they mentioned the following benefits of sensor-based platforms in healthcare:

- continuous monitoring,
- present the information that healthcare professionals needed,
- generate a report on the patient condition,
- real-time monitoring,
- facilitate the work of healthcare professionals, and
- enhance patient care.

Hence, the healthcare professionals considered the benefits of sensor-based platforms to be mutual, in the context that it had benefits for enhancing the patient wellbeing, and it facilitated medical personnel's work. Therefore, participants confirmed that they could propose such platforms for use to their patients in doubt. Nevertheless, the findings on the influence to use the sensor-based platforms, showed a diversity of opinions, as some participants evaluated this as an individual matter of every person.

Further to these findings, this study provided information on different perspectives on the impact of sensor-based platforms on clinical decision making, the number of patient visits, financial aspects, and patient life. Hence, the healthcare professionals confirmed that having a report of measurements on a patient's vital signs, or provision of continuous and remote monitoring, would enable them a more detailed overview and would help in prescribing therapies or changing them according to their effect shown through the values of the vital signs.

When discussing the impact of sensor-based platforms on the number of patient visits, HCPs thought that this number would increase for patients that are not diagnosed, contributing in this way to the early detection of chronic conditions. Here were mentioned also patients who are less informed about their diseases, or have doubts in reading the values of the vital signs, or those who are more sensitive. Nonetheless, there was the other group of healthcare professionals who declared that sensor-based platforms would decrease the number of visits and hospitalization days. These participants perceived that their patients would monitor themselves and would not need to visit the healthcare centre very often, or they would visit only when their doctor said to them to come. However, considering that the interviews were conducted in a private healthcare centre, there were some concerns related to the reduced number of visits, as this would affect the financial aspects of the private institution. However, when considering the financial aspect of a patient, the application of sensor-based platforms was evaluated as costly when bought for the first time, but later it was considered to provide decreases in the family budget.

An interesting finding related to the impact of the sensor-based platforms in a patient's life, besides the benefits mentioned above, was related to the psychological aspect of using them. Hence, participants declared that the continuous application may create concerns, stress, as the patient may not be very informed about his/her disease and may get worried in every alarm. However, this again depends on the patient knowledge about the disease, or the information he/she has on reading the values of the vital signs.

Seen the benefits of the sensor-based platforms, the healthcare professionals proposed their application also inside the hospital, to avoid the usage of wires; remotely, and other healthcare areas such as to help patients and doctors to treat better brain stroke, epileptic activity, and get information about the acceleration of the blood flow to detect blocked vessels that supply the brain with blood.

Data accuracy of the sensor-based devices, according to healthcare professionals may lead to medical errors as they will be monitoring a patient at a distance and will rely solely on the values displayed to them. They perceived that this depends on the sensitivity of the device, not proper settlement of it, for example, the position of the hand, and due to interferences or data loss on wireless communication links. However, healthcare professionals suggested that they should not rely only on the displayed values from the sensor devices, but they should consider also other relevant chronic parameters, the pathology of the disease, a patient's history of the disease, or other examinations and tests.

The healthcare professionals mentioned various challenges for the successful application of sensor-based platforms in a developing country such as Kosovo. These challenges were related to the cost of the sensor-based monitoring, patient collaboration, health insurance, measurement of other parameters, charging method, and artefacts.

5.6 Discussion

Participants in this study had experience in monitoring their patients using digital technology within the hospital premises and also at a distance. However, when monitoring remotely, healthcare professionals did not have real-time access to a patient's vital signs and the devices they used had wires and batteries with a short-lifespan, which affected the monitoring time up to three days (this applied to the digital platforms that healthcare professionals were already using, as discussed in subsection 5.5.3). These two factors limited the remote communication and monitoring provided to patients with chronic illnesses, which may be overcome with the application of sensor-based platforms.

As the HCPs also confirmed, the application of sensor-based platforms would enable vital signs to be read continuously, which would enable them to have a better view of a patient's condition and the history of their vital signs for a longer period of time and, according to participants in this study, this could also improve the effectiveness of the treatment. This has an important contribution especially for developing countries such as Kosovo, considering the health-related challenges that they are facing, such as access to medical services, a limited number of medical centres and resources, financial constraints, and a limited number of healthcare professionals to treat the increasing number of patients diagnosed with chronic illnesses. Although many countries are facing increased demands for healthcare services, this is particularly the case for developing countries.

Hence, the focus of this research work is to propose a sensor-based architecture (as presented in the next chapter 6), considering the results of this interview study, for developing countries to help them manage the increasing number of people diagnosed with chronic conditions and improve the access to health services seeing the limited number of healthcare centres, resources, equipment, and medical personnel (as elaborated also in section 1.4). Nevertheless, this does not mean that the findings discussed here may not apply to other similar countries that are facing similar issues. The applicability of the findings will be dependent on the local and regional context.

A model-driven discussion aims to provide knowledge and guidance on the technological factors (section 2.5) that affect the adoption of sensor-based platforms for monitoring vital signs. Hence, the TAM2 model was not used, as the subjective norm did not apply to this study (Dünnebeil, et al. 2012). The task-technology fit model presented the opposite logic of the methods applied in this study (Goodhue, 1995). Consequently, for understanding the application of sensor-based platforms for continuous and remote monitoring of patient's vital signs, this study used TAM and incorporated some additional variables because, as Holden and Karsh (2010) concluded, the technology acceptance models needed a future direction to be adapted for the healthcare setting. The truth-telling variable was discussed by healthcare professionals in this study as an additional factor that needs consideration while using sensor-based platforms for remote and continuous vital sign monitoring. This is considered as another contribution of this study to the health informatics research area. Further details and the relationships among these variables are discussed in the following subsections.

5.6.1 Perceived usefulness

This concept describes the degree to which the users, in this study the healthcare professionals, think that the application of sensor-based platforms for continuous and remote monitoring will improve their performance towards monitoring vital signs of their patients with chronic illness. The findings showed that healthcare professionals perceived these platforms as useful to apply, even for distance-based patients, for example:

> *"I think it would be something very good, and it would increase the effectiveness and productivity of our treatment." (Interview 24. Doctor)*

Moreover, the participants seemed to like the digital systems that they were already using to monitor patients. This was also clear when discussing the importance of monitoring vital signs (as reported in subsection 5.5.6). The perceived usefulness of applying digital technology in healthcare was described also when a patient's condition was critical and the medical personnel was using the wired-digital system to set a frequent measuring interval for that patient.

Nevertheless, this study showed differences in the perceived usefulness of sensor-based platforms according to the HCP's background, as suggested in another study by Davis et al. (2014). Hence, in this thesis, doctors were willing to use remote and digital monitoring technologies, while nurses showed some resistance in this context. For example, there were cases where they were using manual devices to measure the same chronic parameters that they already measured using the digital system, as explained:

> *"There are cases where we measure patient's blood pressure with manual one [manual device] if we do not like that we see on the digital monitor." (Interview 17. Nurse)*

Moreover, the nurses seemed to mistrust the digital technologies and they preferred to use paper sheets to record their patients' vital signs, or document other information relating to a patient's condition. This was also concluded by Koivunen and Saranto (2018), who performed a systematic literature review that included twenty-five studies related to nurses' attitudes to using digital technologies. This study found that nurses' concerns about confidentiality and data security were factors that indicated that they had a negative attitude towards e-health.

5.6.2 Perceived ease of use

This concept describes the degree to which the users (in this case the healthcare professionals) think that the application of sensor-based platforms for continuous and remote monitoring of vital signs will be effortless to use. In this context, the HCPs, taking into consideration their experience with the already implemented digital technologies, confirmed that:

> *"It was nothing. You select the button to measure the blood pressure and blow out the cuff and it displays in the screen." (Interview 7. Doctor)*

> *"It was not difficult. It was easy. Of course, while they get printed [i.e., patient's report printed from the digital system] someone told us and we have learned it very well [they received training]." (Interview 21. Nurse)*

The healthcare professionals seemed to have adopted the existing system easily and this was also the case for the Holter monitors and the CGM that were used for remote monitoring.

5.6.3 Behavioural intention

Considering the usefulness of sensor-based platforms for remote and continuous monitoring of vital signs, the participants expressed interest in using them. The focus of healthcare professionals was to apply sensor-based devices to have a better view of the patient's condition for longer periods of time, for example:

“It means it is different when you see patient’s values all the time, and different not to have the view at all. It is better to also monitor the patient continuously, to see how he/she is feeling.” (Interview 11. Doctor)

“I am saying that sometimes I think of how to implement an idea that is less annoying for the patient and can give us more data. I like very much these in distance [sensor-based monitoring].” (Interview 25. Doctor)

However, as Steel, Secombe, and Wong (2009) reported, users will accept remote monitoring technologies as long as they provide the benefits they are supposed to and are easy to use.

5.6.4 Actual usage

Holter monitors were placed on chronically ill patients to monitor their heart activity and blood pressure at a distance. These devices had sensors and were used to monitor patients for 24, or 48, or 72 hours continuously while the patient was outside the clinic. The patient had to bring the device back after it had recorded his/her vital signs continuously for the period of time set by the doctor. When the patient returned the device, a nurse would connect the Holter device to a computer and prepare the ECG graph or blood pressure values for the doctor to read them.

“24-hour Holter monitoring means recording of heartbeats for 24 hours, they are recorded on a disk which is inserted in the PC and we can see what happened with the patient within 24 hours.” (Interview 12. Doctor)

This presents an actual example of using sensor-based platforms to monitor a patient’s vital signs remotely. However, the HCPs did not have access to these recordings until the patients brought back the device in the clinic, this practical limitation could be improved using secure web-based technologies to transfer the data.

5.6.5 Performance expectancy and job relevance

The healthcare professionals confirmed that the application of digital technology affected their job performance and helped them complete tasks easily (the usefulness and ease of use aspect), for example:

“Compared to the traditional methods, measuring with cuff, putting the stethoscope, checking whether you are listening well; now we have the digital monitoring system that we can assign to measure the vital signs every 5 min, every 10 min, every 15 min, and it just shows us the results and we monitor the patient.” (Interview 16. Nurse)

“I put a Holter to see if there is a pause. If the rhythm has slowed down so much that can give any significant pause, for example, those 2-3-second pauses are important and can justify the placement of a pacemaker. So, it has its importance.” (Interview 7. Doctor)

These comments confirm the impact of digital technologies on healthcare professionals’ everyday work and performance for monitoring a patient’s vital signs. Moreover, some participants described how they could arrange visits with patients according to the remote and real-time data that they received from the sensor-based platforms. Considering these examples and the study results, it is clear that there is a connection between the performance expectancy and job relevance with the perceived usefulness and ease of use.

5.6.6 Social influence

The actual usage and the behaviour intention to use more advanced digital platforms had an impact on the social influence variable as discussed in this research. Healthcare professionals were proud of using the continuous monitoring system for hospitalized patients and also the Holter monitors and CGM for remote patients. As they said:

> *"This here is very advanced technology. And for the moment, the American Hospital, in comparison with the region, has the most advanced technology and equipment. So, it is a great relief to our work that we do every day." (Interview 3. Doctor)*

> *"I think that this system is very good. Because in Kosovo there is not a better one. Now if we compare the public hospital and this one (.) only in foreign countries are these luxuries I can say. "(Interview 11. Doctor)*

Hence, it is clear that the social influence was to adopt advanced digital technologies in healthcare, considering that Kosovo has only one public healthcare centre where tertiary services are provided.

5.6.7 Truth-telling

This study also investigated truth-telling in critical situations (as described in subsection 5.5.6.6) while using sensor-based platforms. The healthcare professionals in this study declared that, in such circumstances, they preferred not to let the patient know about these values but to react quicker with therapies and after the patient's condition had stabilized, then to tell them the truth. In this context, Resnik (2001) supported healthcare professionals in withholding the truth from their patients only in cases when they had evidence that it would cause harm to them. However, there is a fine line between protecting the patient from potential harm and being paternalistic.

Sullivan, Menapace, and White (2011) performed a study on the patient's point of view, and they confirmed that the vast majority of patients wanted to know about their conditions. This applies also to this study as the patients were supposed to use sensor-based platforms for continuous and real-time recording of their vital signs, and they would have these data and could also see their condition. In this context, Rexhepi et al. (2016) confirmed that online access that patients had to their data seemed to have helped them prepare for the visits with doctors. Therefore, the shared decision making (SDM) proposed by Elwyn et. al (2012) included a three-step method (1. presenting a choice, 2. describing the options, and 3. elaborating the offered conditions and making decisions) that would improve the decision making in healthcare while involving also the patient.

5.7 Strengths and limitations

This study aimed to identify healthcare professionals' attitudes towards vital sign monitoring using sensor-based platforms as remote and continuous monitoring platforms. By undertaking a qualitative interview study, this research was able to gain an in-depth understanding of the views of HCPs. However, this interview study had some limitations.

First, this is a relatively small-scale qualitative study, and the sample may not be representative of healthcare professionals within Kosovo. This may affect the generalizability of the findings to the wider population. However, the purpose of qualitative research is not necessarily to yield generalizable results but to develop a detailed understanding of the relevant issues, which might then be applicable, or transferable, to similar groups affected by these issues. Given the detailed understanding that was developed, there is no reason why the findings are not transferrable to other similar healthcare institutions in Kosovo and, potentially, in other developing countries that are facing similar challenges with increasing numbers of patients will chronic illnesses and limitations on access to health care services and resources.

Second, the healthcare professionals had limited experience with sensor-based platforms for real-time and distance-based monitoring. However, some participants were using monitoring systems within the hospital and patients were being monitored at home for short periods, so their insights from these experiences provided a useful contribution to the understanding of the issues. Additionally, they expressed interest in applying these technologies to monitor their patients remotely at home over longer periods of time and they were, therefore, able to engage with the concepts in applying these technologies.

Despite the limitations discussed above, the findings presented in this study can inform and be used to provide recommendations to system developers of sensor-based platforms about the attitudes, views, and opinions of healthcare professionals on using such applications for monitoring their chronically ill patients remotely and continuously.

5.8 Conclusions

This chapter presented the findings of the first interview study related to the healthcare professionals' experience in using digital technologies and their attitudes and perceptions towards the application of sensor-based platforms for continuous and remote monitoring of the vital signs for patients with chronic illness, in Kosovo, a developing country. Participants were from various clinical areas, most of them had a university degree, almost two-thirds of them had more than 3 years of working experience, some of them were working as full-time cardiologists in the public healthcare centre (UCCK), and all of these healthcare professionals were monitoring parameters related to chronic diseases.

The findings of this study contributed to new knowledge on the adoption and acceptance of sensor-based platforms in a SEE developing country, Kosovo, considering that no previous research was reported in this regard. Further details on the answers to the research questions of this interview study and the key findings are elaborated in the following subsections.

5.8.1 Research questions outcomes

The findings of this interview study provided answers to the research questions formulated before the interviewing process (section 5.2). Hence, below are presented the predefined research questions and the corresponding sections that provide the specific answers.

1. In what context, will the application of sensor-based platforms help a developing country, Kosovo in this case, to treat and manage chronic diseases?

This research question was addressed in subsections 5.5.3.1, 5.5.8.1, and 5.5.8.4. Therefore, the application of the sensor-based platforms would help patients with chronic illness to get regular check-ups, early diagnosis, and in this way to possibly avoid distances or critical cases. Participants confirmed that they have a limited number of resources to treat chronic diseases. Hence, the application of sensor-based platforms can affect the number of visits, and lower hospitalization days.

2. What may be the factors that can challenge the implementation of SBN in the health system of a developing country such as Kosovo?

   This research question was addressed in subsection 5.5.8.8. Hence, the cost was identified as the primary factor that may challenge the successful implementation of sensor-based platforms in a developing country, such as Kosovo. Further to this, the lack of health insurance, patient collaboration, artefacts, and charging method, were mentioned as additional factors that need careful consideration.

3. What are possible recommendations for a successful implementation of an SBN architecture in a developing country, Kosovo?

   The recommendations for a successful implementation of sensor-based platforms were elaborated through the corresponding themes as presented in subsections 5.5.8.3, and 5.5.8.6. Hence, the healthcare professionals recommended that the sensor-based platform should be easy to carry, accurate, cheap, gather the information that they need, and should provide alarms in critical situations. Moreover, participants recommended having a method of recording the distance-based communication between the patient and the medical personnel. Possible financial support for the healthcare professionals that provide feedback to patients at a distance, was mentioned as very important for the successful implementation of the sensor-based architecture. Furthermore, some overloaded doctors proposed additional people who could provide information based on gathered sensor data. As they said a family doctor, a specialized nurse, or young doctors without academic obligations, can help more in this context.

4. How will the application of sensor-based networks affect healthcare professionals' work and patient care?

   The details on the benefits of using sensor-based platforms for the healthcare professionals and the patient, that answer this research question are elaborated in subsection 5.5.8.2. The identified benefits include continuous monitoring, provision of the information that healthcare professionals need, generation of a report with measurements on a patient condition, real-time monitoring, facilitates the clinical decision making, affects the number of visits, and hospitalization days.

The findings of the interview study revealed also other details related to healthcare professionals' attitude and acceptance of the sensor-based applications as the following subsection presents.

5.8.2 Key findings

This study identified a group of underlying themes and a set of information related to the successful implementation of the sensor-based architecture. Therefore, the most important findings arising from this interview study are as follows:

a) **there were key vital signs** (i.e., blood pressure, pulse, temperature, heart rate, oxygen saturation) that healthcare professionals needed to monitor continuously and, based on these, to provide reliable feedback to their patients. Hence, it is recommended that the sensor-based architecture should provide values of these vital signs;
b) **the condition of various organs of the human body also dictates the critical values** of these chronic parameters and their **frequency of measuring** and this should be considered in the design of the sensor-based architecture;
c) **the impact of applying a sensor-based platform for monitoring vital signs and the usefulness of having a historical, i.e., longitudinal, recording** of a patient's condition in the early diagnosis of chronic diseases, which can lead to better treatment in the context of any therapies that are applied subsequently.
d) **truth-telling,** emerged as a new technology acceptance variable from this study: this was considered important to investigate when designing and implementing digital technologies for healthcare that include the patient's access.

The model-based discussion on the healthcare professionals' perceptions on using sensor-based platforms for continuous and remote monitoring of vital signs showed that **doctors perceived the platform to be useful** (**d)** to enhance the communication between the patient and them, and **e)** to improve the access to health data and care). **This has an impact on the behavioural intention to use and job relevance** (**f)** early identification of chronic conditions, **g)** report on vital signs' values for longer periods of time, **h)** accurate diagnosis), **and ease of use for the healthcare professionals**. On the other hand, **for the patients, the ease of use seemed to affect the truth-telling** as the patient would have direct access to his/her medical data.

Hence, the results of this study: (1) provided recommendations for system designers and implementers on what is an acceptable sensor-based platform based on the users' perceptions, and (2) presented a rigorous way on how to combine the factors that affect technology acceptance in the healthcare setting to improve the system design and implementation.

As part of the next phase of work, and following the results of this qualitative study, this thesis focused on the integration of a sensor-based architecture that will take into account the findings of this study, as presented in the next chapter.

Chapter 6 Design and implementation of the sensor-based prototype

6.1 Introduction

The findings of the interview study with healthcare professionals, as presented in the previous chapter 5, provided information on the current health practices, and suggestions on the functionalities that the users will need to provide remote and continuous monitoring to their chronically ill patients. All these details are elaborated and considered during the design of a sensor-based architecture and the implementation of the prototype (SBNHealth), which are discussed in this chapter.

Hence, this chapter primarily presents the design of the proposed sensor-based architecture on the high-level schema in section 6.2. The recommendations that emerged from the interview study with healthcare professionals and were considered in this chapter are elaborated in section 6.3. Following the general schema and the list of recommendations, a layered sensor-based model is discussed in section 6.4. The context model that breaks down the components of the proposed architecture is presented in section 6.5. Section 6.6 shows a use case diagram with the functionalities of the patient and the healthcare professional with the proposed SBNHealth prototype. The details on the implementation process of the mobile application and the web-based application of the proposed sensor-based prototype, are elaborated in detail in section 6.7. The proposed SBNHealth was build-up based on some assumptions and has some limitations as discussed in section 6.8. Finally, section 6.9 concludes the contribution of this chapter.

6.2 High-level system architecture

Following the aim of this study (section 1.5), and considering the findings of the empirical research presented in the previous chapter 5, the general architecture of a sensor-based platform for the healthcare settings includes the patient who provides data to the system and the medical personnel who monitors and provides feedback according to the provided information. These data, which represent a patient's vital signs (i.e., blood pressure, oxygen saturation, heart rate), are routed through several points before they are presented to the monitoring personnel, as presented in Figure 6.1.

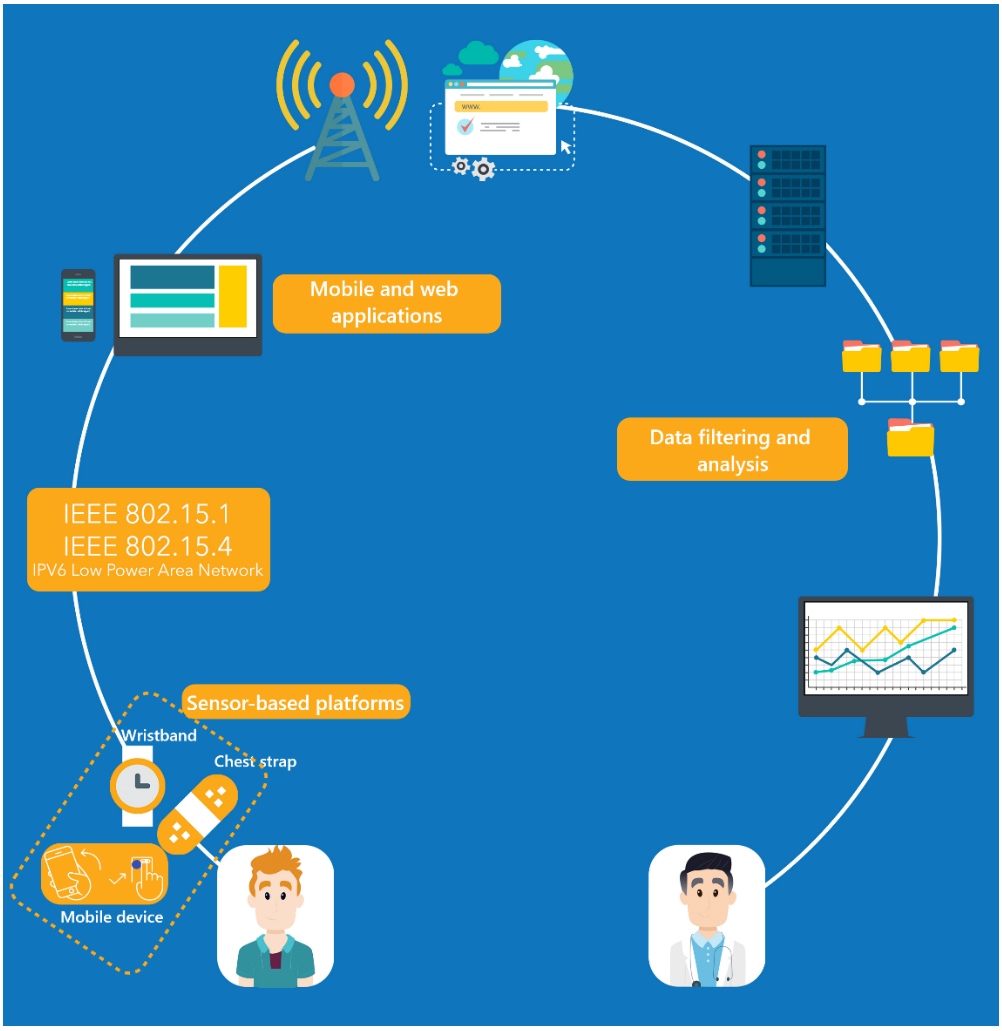


Figure 6.1 High-level system architecture

As shown in Figure 6.1, the proposed architecture includes the patient using the sensor-based unit, which can be a mobile device or a wristband or chest strap. This architecture uses wireless communication links or other protocols, to transfer the gathered data, respectively, a patient's vital signs to a remote storage point. Data analyses and filtering may be performed on the transferred information, which is then presented to healthcare professionals in the form of graphs, tables, or numeric values, as suggested by them (subsection 5.5.8.6).

Consequently, the proposed high-level system architecture presents a feasible solution that supports the real-time and continuous monitoring of patients with chronic illnesses, addresses the needs of the pervasive and unobtrusiveness healthcare, and enables monitoring of five vital signs proposed by healthcare professionals of the interview study, respectively: heart rate, blood pressure, pulse, temperature, and oxygen saturation. Further recommendations arising from the first interview study with the healthcare professionals that provide the building blocks of the sensor-based architecture are presented in the next section.

6.3 Recommendations arising from the interview study

From the results of the interview study presented in chapter 5, it is concluded that healthcare professionals were willing to collaborate to apply a sensor-based platform for remote and continuous monitoring of the patients with chronic illnesses in a developing country such as Kosovo. Hence, there emerged several design considerations or functionalities that healthcare professionals suggested.

The healthcare professionals' suggestions and this study consideration and inclusion in the design of the sensor-based architecture, are as follows:

- Monitoring Units
  The proposed sensor-based architecture will be used by patients who will access their vital signs in their mobile devices in real-time and healthcare professionals who will access their patient's vital signs using a web-based application. The proposal about the monitoring units was based on healthcare professionals' suggestions and also the aim and objectives of this study. Furthermore, this is related to the key findings listed in subsection 5.8.2, specifically point a).

- Provision of alarms/notifications in critical conditions
  The healthcare professionals preferred to receive alarms or notifications that would alert them about their patients' conditions. This is related to the key findings listed in subsection 5.8.2, specifically points f) and e).

- Set a range of normal values of vital signs
  During the interview study, while discussing the critical range of values for the vital signs (subsection 5.5.6.3), healthcare professionals declared that there can be a flexible range according to the patient's body and the anamnesis. Therefore, this study has considered this suggestion and included in the design of the sensor-based architecture, the possibility for the healthcare professionals to set the critical interval of values for every patient. This is related to the key findings listed in subsection 5.8.2, specifically point b).

- The possibility to filter patients
  Participants of the interview study suggested having a possibility to filter patients, for example, to display first patients that are in critical condition. This was also included in the design and implementation of the sensor-based architecture. This is related to the key findings listed in subsection 5.8.2, specifically point c).

- Data access only from authorized personnel
  Data security was raised as a challenge for the successful implementation of sensor-based platforms by healthcare professionals during the interview study. To address this, the designed architecture used authentication on both users' levels and data encryption. Moreover, a random code was generated and saved for every patient so that only healthcare professionals who have it, can access a patient's data. This is related to the key findings listed in subsection 5.8.2, specifically point h).

- Recording interval of vital signs
  The healthcare professionals declared they usually, in normal conditions, measure a patient's vital signs every two hours. However, in critical cases, they set the digital monitoring system

(subsection 5.5.3) to measure the vital signs more often. According to this information, there were included three different transmission modes as presented in subsection 6.4.2. This is related to the key findings listed in subsection 5.8.2, specifically point b).

- Provide a summary (report) of the patient's vital signs
  To see a patient's condition for a longer period of time (i.e., weeks, or months), healthcare professionals wanted the sensor-based architecture to summarize the patient's data. Hence, the proposed sensor-based architecture, in both its units, the mobile application, and the web-based application, has incorporated the functionalities to provide this information. This is related to the key findings listed in subsection 5.8.2, specifically point g).

- Presentation of health data
  The HCPs who participated in the first interview study wanted a simple presentation format of the patient's vital signs values and also the possibility to compare and see the values in different intervals of time. They proposed graphs and tables for presenting a patient's vital sign values. This is related to the key findings listed in subsection 5.8.2, specifically point e).

- Monitoring personnel
  The proposed sensor-based architecture in this study is intended to suit the 1:1 scenario, one doctor monitoring one patient, and also the 1: N scenario, in the context of having medical personnel that will monitor several patients. This was as the healthcare professionals suggested, i.e., that for distance-based monitoring there should be a personal or family doctor, or specialized nurse, or a call centre to provide feedback to patients at a distance. This is related to the key findings listed in subsection 5.8.2, specifically point d).

All the above concepts, present functionalities that were included in the proposal of the sensor-based architecture presented in this chapter. In this way, the users' recommendations were interpreted into software engineering requirements for further design and implementation. Hence, the following section elaborates more in detail the three layers of the sensor-based architecture, considering the recommendation presented here.

6.4 Layered sensor-based architecture

The sensor-based architecture proposed here consists of three layers: the sensing layer, the transmission layer, and the application layer, as presented in Figure 6.2.

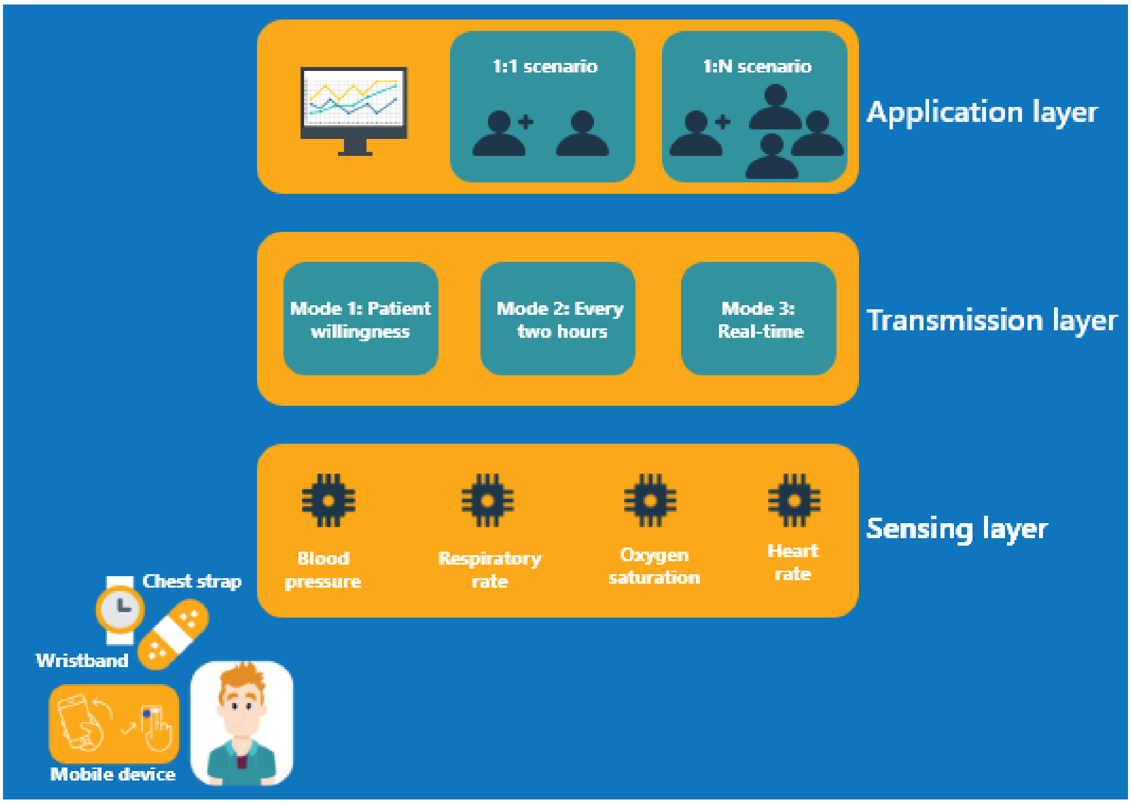


Figure 6.2 Layered sensor-based architecture

The three layers shown in Figure 6.2, present three general categories used in other related studies (section 2.4), however, this study adapted them according to the investigated needs and attitudes of the healthcare professionals in this study in Kosovo. The following subsections present brief information on the sensing, transmission, and application layers of the proposed architecture.

6.4.1 Sensing layer

This layer of the system architecture is composed of sensors that collect data on a patient's vital signs. Different sensors may be integrated into a single platform, as presented in Figure 6.1 in a mobile unit, wristband, patch, or chest strap, to provide a compact product that can be carried by the patient to record his/her values of the vital signs. The selection of the sensors is based on the parameters that healthcare professionals need to track. Therefore, considering the results of the interview study presented in chapter 5, the sensor-based platform may consist of sensors that provide values of the heart rate, blood pressure, pulse, temperature, and oxygen saturation, as presented in Figure 6.2.

6.4.2 Transmission layer

The transmission layer of the proposed sensor-based architecture is designed to transmit gathered sensor data to the upper application layer, as elaborated in the next subsection. Hence, to address the healthcare professionals' needs, and based on a previous work presented by Li, Hu, and Zhang (2017), this layer is designed to operate in three different transmission modes, as follows:

Mode 1: Patient willingness

During the interview study, healthcare professionals talked about the huge volume of the patient's data and the workload of the doctors to analyse them and provide feedback to patients. Hence, to solve this challenge, this study designed the transmission mode that forwards a patient’s data based on his/her willingness. This means that gathered sensor data will be stored locally in the patient’s connector device (i.e., mobile phone) and when he/she does not feel comfortable and requests the doctor’s advice can press a button to send the history of the gathered sensor data to the doctor (Appendix C.4).

Mode 2: Every two hours

In this mode, the sensor-based architecture transmits data in a predefined interval of time. Healthcare professionals of the interview study (subsection 5.5.6.4) confirmed to measure a patient’s vital signs every two hours when the patient’s condition was relaxed. Hence, this health practice was included also in the proposed sensor-based architecture, and as such, it is not adjustable.

Mode 3: Real-time

In this mode, the proposed architecture transmits data all the time. Hence, the doctor evaluates the patient’s condition and in critical circumstances, he/she chooses this transmission mode. This is closely related to the already implemented digital monitoring system in the American Hospital in Kosovo, where the interview study was conducted. The healthcare professionals there confirmed that, in critical situations, they needed to monitor the patient all the time.

The motivation for using different modes of transmission is closely related also with the power consumption of the sensor-based platform, which was discussed also by healthcare professionals as a challenge for successful implementation of the sensor-based applications (subsection 5.5.8.8). This means that, if the transmission time is coordinated and if only necessary resources are used, then the data are transmitted when needed and this can help to lower the power consumption of the mobile unit.

6.4.3 Application layer

The application layer of the proposed sensor-based architecture aims to analyse and filter the transmitted vital signs in a simple and understandable format for presentation to enable healthcare professionals’ easier access to them. According to the healthcare professionals’ proposals (subsection 5.5.8.6), the collected patient data may be presented using graphs, tables, or numerical values.

In their study Saponara, Donati, Fanucci, and Celli (2016) proposed three different scenarios on how to apply sensor-based architectures in practice. These scenarios were related to 1:1 pair of communication, meaning one doctor monitors one patient; 1:N pair of communication, in the context that the healthcare centre will assign medical personnel that will monitor patients; and the “point of care” scenario that was based on the implementation of the sensor-based platform in a local building (i.e., a pharmacy) where patients can visit and monitor their health parameters which then will be saved in the remote servers of the platform.

Nevertheless, the proposed sensor-based architecture in this study, as shown in Figure 6.2, aims to suit the 1:1 scenario described above and also the 1:N scenario, but in the context of having a healthcare professional that will monitor several patients. This is according to healthcare professionals' opinions that, for distance-based monitoring, there should be a personal or family doctor, or specialized nurse, or a call centre to give feedback to patients at a distance.

The following section breaks down the system architecture into a context model that includes more specific components as presented there.

6.5 Context Model

The details on the healthcare professionals' recommendations and the layered architecture presented in Figure 6.2, make it easier to break down the proposed sensor-based system into smaller units and understand the data flow through the architecture modules. Hence, the components included here are a representation of the functionalities that were already proposed by the users of the system. A full view of the sensor-based architecture from the context model's point of view is shown in Figure 6.3, and it consists of three communication platforms or units, such as the wearable kit (mobile unit, wristband, or chest strap), the mobile monitoring device, and the web monitoring unit.

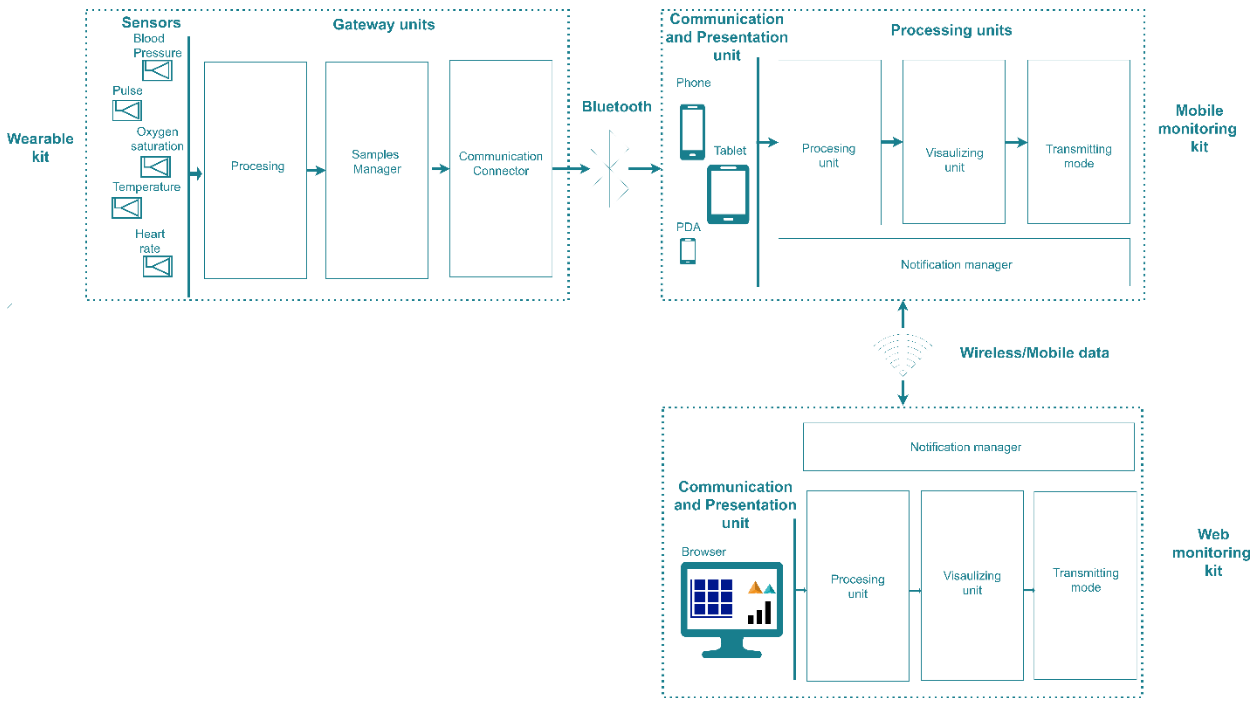


Figure 6.3 Context model of the proposed sensor-based architecture

The wearable kit, shown in Figure 6.3, consists of sensors that measure a patient's vital signs continuously and remotely. There are included the five sensors according to the five vital signs that most of the healthcare professionals mentioned they needed to monitor in their chronically ill patients, i.e., blood pressure, oxygen saturation, pulse, temperature, and heart rate. The gathered sensor information is processed, and sampled into data packets, for further routing that is enabled through the communication connector presented in Figure 6.3.

The communication connector establishes and maintains the communication with the mobile monitoring kit, to transfer the gathered sensor data from the sensor-based unit. In this case, Bluetooth low-energy technologies may be used to transfer data that represent a patient’s vital signs. The mobile unit can be a smartphone, PDA, or a tablet with an Android operating system (to support the installation on the implemented SBNHealth mobile app, as presented in subsection 6.7.1). Therefore, the patient can access and see visualized sensor data using the mobile monitoring unit.

As presented in Figure 6.3, the doctor can access a patient’s vital signs using the web monitoring unit. The figure shows some common components between the mobile and the web monitoring units. The processing unit is designed to manage the flow of the information, i.e., display the information coming from the sensor-based device, enable notifications, and similar. The notification manager is a key module that manages notifications sent from the doctor to the patient (changes to data transmission modes). These notifications, if approved by the patient, determine the transmission mode of the gathered sensor data from the mobile unit to the web unit, which is managed through the transmitting mode component. The visualizing unit is used to present the patient’s information in a readable and understandable form (graphs, tables, or numerical values) for the patient and the healthcare professional.

The proposed sensor-based architecture will be used by the patients who will access their vital signs in their mobile devices in real-time, and by the healthcare professionals who will read their patient’s vital signs using a web-based application. Hence, the following subsections present information on the data flow in both perspectives, the patient and the HCP.

6.5.1 Patient’s data flow diagram

The data flow diagram that represents the patient's point of view while using the proposed sensor-based architecture is presented in Figure 6.4. As shown in the figure, the patient will have a mobile unit to use the sensors for that device, for recording his/her vital signs. These actions are performed inside a data acquisition level. For the system proposed in this thesis, the patient will use a mobile device, based on an Android operating system, and will benefit from its sensors.

The connector device manager located in the mobile device is responsible to initiate a connection with the sensor-based unit and maintain that communication channel. If the connection is lost or interrupted then the transmitter connection and connection handler components, as presented in Figure 6.4, will try to reinitialize and recreate the connection.

The other unit of a patient’s data flow diagram consists of components related to the mobile monitoring kit, i.e., the smartphone. This module is designed to be responsible for further processing the gathered sensor data, by transmitting them based on the transmission mode, or providing any notifications based on the patient's health condition, and visualize the measured vital signs to the patient in their mobile unit, i.e., smartphone. Further to this, this mobile monitoring module is designed to include also the local storage that is needed for *Mode 1: Patient willingness*, of data transmission (subsection 6.4.2). Hence, as it is discussed in detail during the implementation (subsection 6.7.1.3) when the patient is transmitting on mode 1, gathered data are saved locally in the mobile monitoring unit and are forwarded to the healthcare professionals when the patient decides to do so (i.e., click the *Share with the doctor*, button). Nevertheless, when the patient is transmitting data on the other two modes (mode 2 and mode 3), the gathered vital signs are transmitted through the communication connector further to the server module.

The third module of the patient's data flow diagram uses an Internet connection (wireless or mobile data) as a communication connector and communication handler between the mobile device and the server part. This means that the sensor data that are stored locally (if transmission mode 1 is enabled) and those generated periodically (mode 2) or in real-time (mode 3), will be transferred to the remote server for further analysis and storage. The visualization and GUI components get the filtered and analysed data, and present them to the medical personnel who can access them and provide feedback to their remote patients.

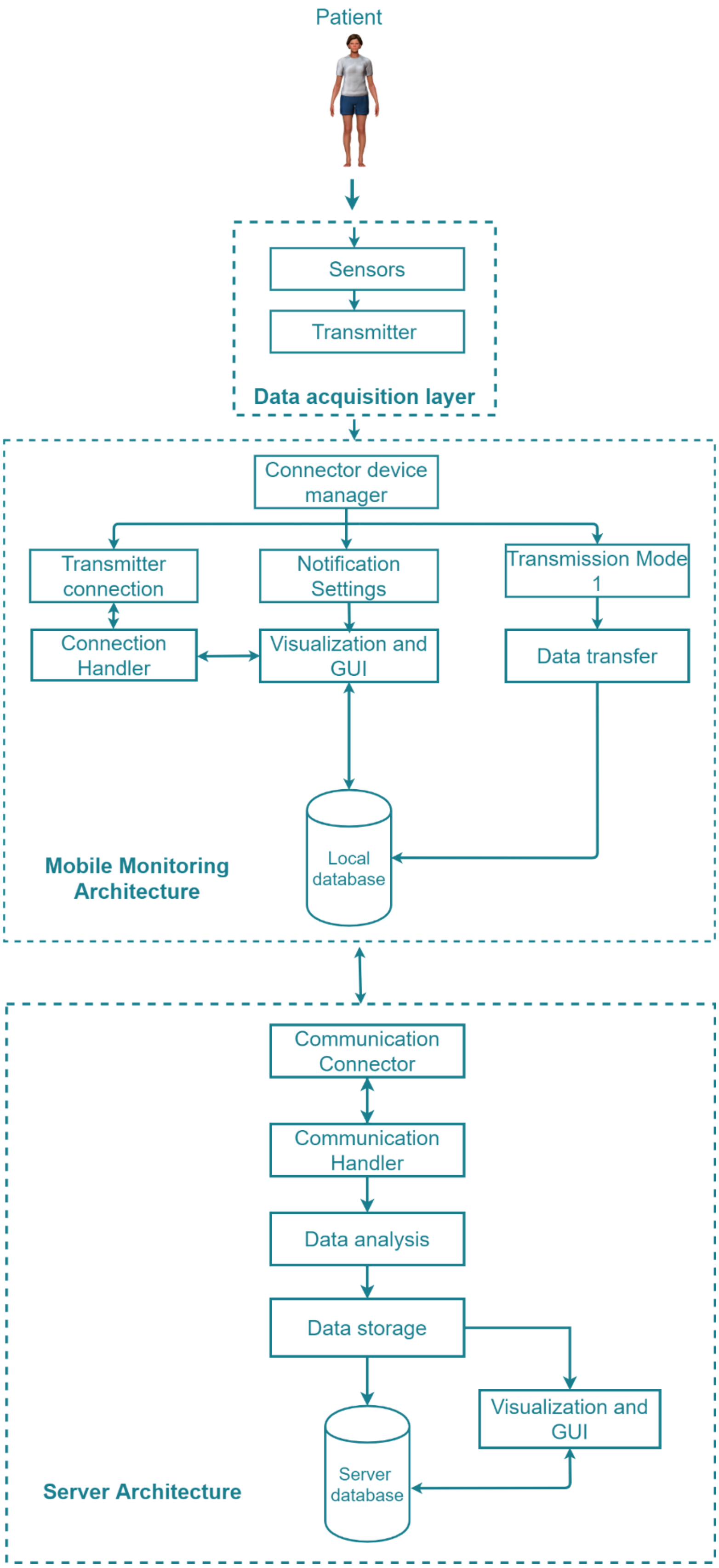


Figure 6.4 Data flow diagram that represents the patient point of view while using the proposed sensor-based architecture

The diagram presented in Figure 6.4 visualizes the communication and components of the proposed sensor-based prototype from the patient's point of view. Furthermore, the server level module which is presented in the high-level system architecture in Figure 6.1, is a common unit that is used also in the healthcare professional's data flow diagram, as presented in the next subsection.

6.5.2 Healthcare professional's data flow diagram

The data flow diagram that represents the HCP's point of view while using the proposed sensor-based architecture is presented in Figure 6.5. As shown in the figure, the proposed system architecture uses an authentication component that presents a security step to ensure that only authorized medical personnel can access a patient's data. This authentication component enables the generation of a unique random code that is shared between the patient and the monitoring medical staff. Furthermore, both parties, the patient and the HCP, need to create accounts for which their data are encrypted and they need to log in with those account details afterward.

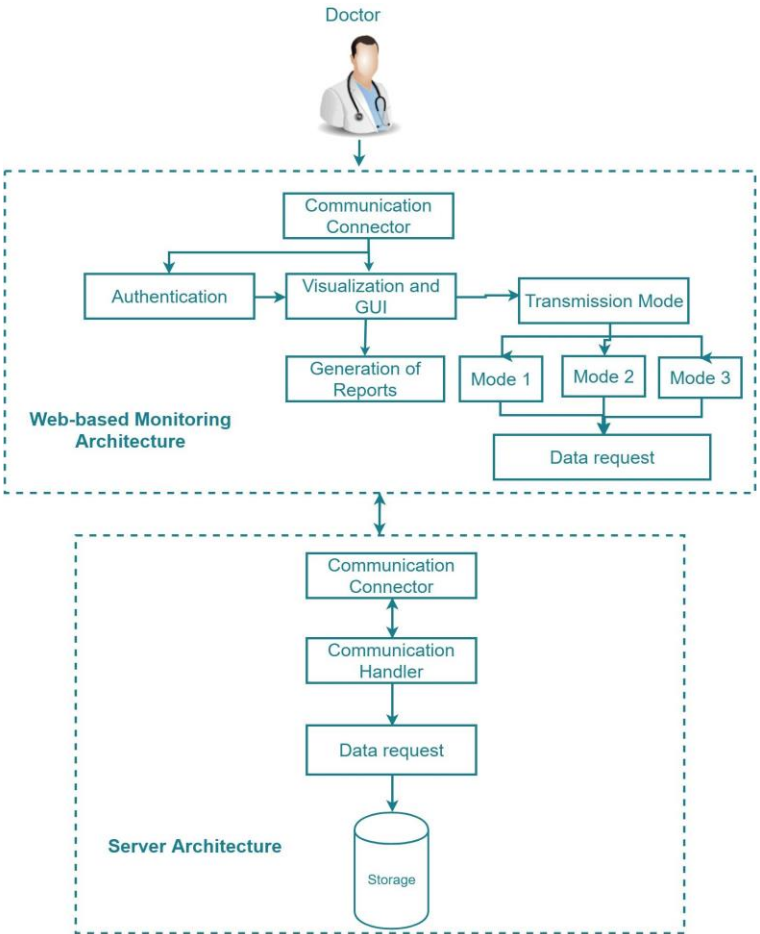


Figure 6.5 Data flow diagram that represents the healthcare professional's point of view while using the proposed sensor-based architecture

Besides accessing, viewing, and comparing reports that provide brief information on a patient's condition, the HCP can also set the transmission mode. Hence, based on the patient's condition the doctor may request that the sensor-based architecture transmits data all the time (transmission mode 3), every two hours (transmission mode 2), or leave it as it is by default, on patient willingness (transmission mode 1). In this case, the patient will get a notification (the notifications settings in

Figure 6.4) and if approved by the patient, his/her vital signs will be transmitted in the agreed transmission mode.

Consequently, the context model and data flow diagrams provide a step further towards the functionalities that the proposed sensor-based prototype includes, and that are elaborated in the next section.

6.6 System Requirements

This section presents the system requirements based on the users of the system. The participants of the interview study helped this research to develop a clear view of the functionalities that they needed to have in the sensor-based continuous and remote monitoring system. Figure 6.6 presents a use case diagram that visualizes the system requirements.

A use case diagram shows the actions that the user performs with the system (Larman, 2004). The arrows indicate the direction of the communication and who will be performing it. The ellipses present an action's description that the system needs to perform. In the use case diagram, when one action is dependent on another action it is represented with the <<include>> relationship, while the <<extend>> relationship presents the case when one action is an extension of another action.

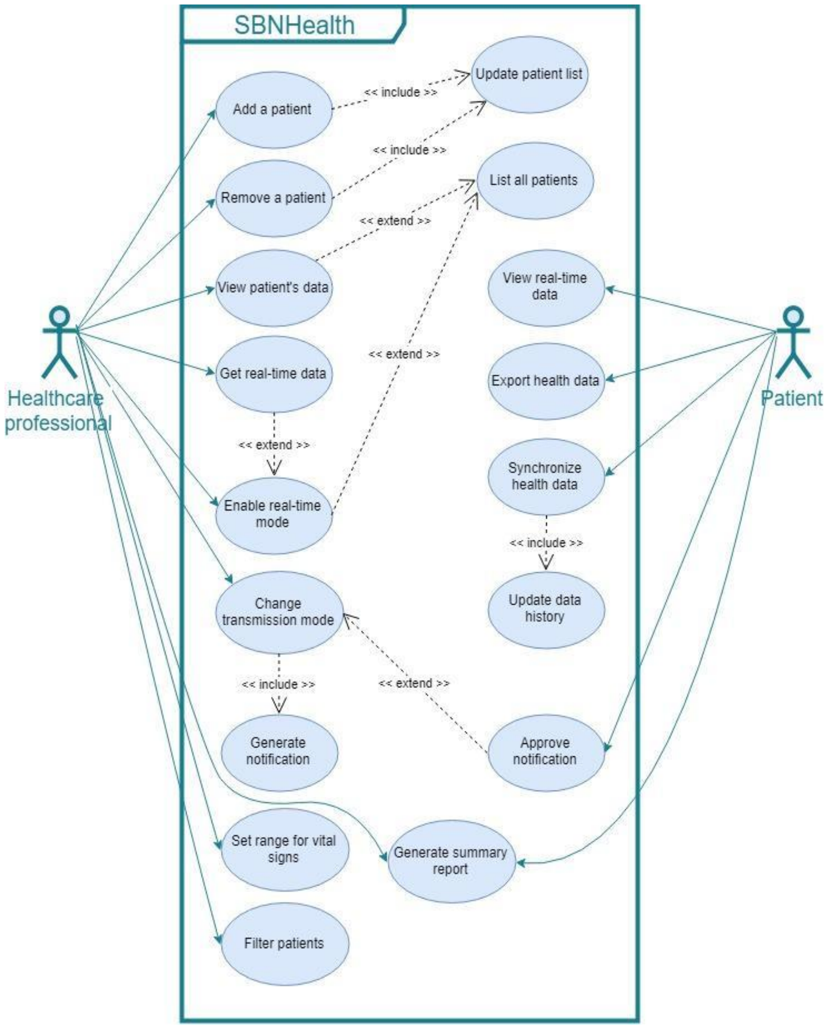


Figure 6.6 System requirements through the use case diagram

The actions presented in Figure 6.6 present users' functionalities that they can perform with the proposed sensor-based prototype. They all arise from the recommendations discussed in section 6.3, and considering the latest medical and ethical practices, i.e., the changes to data transmission modes (as there were needed different modes) that were approved by the patient (who provides consent to access his/her vital signs), and similar actions. Further details on the implementation process of these functionalities are presented in the following section.

6.7 Implementation of the proposed sensor-based prototype

This section provides information on the implementation process for the proposed sensor-based prototype, SBNHealth. The SBNHealth system consists of two parts, the Android mobile application (subsection 6.7.1), which is supposed to be used by the patient and includes all the functionalities that the patient can perform with it (as presented in Figure 6.6), and the web-based application (subsection 6.7.2), which is supposed to be used by the healthcare professionals to perform the functionalities related to remote and continuous monitoring of their patients.

Throughout this section are presented the logical overview and steps for performing the functionalities of the proposed sensor-based prototype. The corresponding source code of the implementation of the SBNHealth prototype is accessible from the author, upon request[7].

6.7.1 Implementation of the mobile application

The mobile application was implemented using Java programming language for the Android operating system on mobile devices with versions starting from Android 16 and above, that have heart rate sensors included. All the functionalities related to the patient as presented in Figure 6.6, were implemented using native Java code. An overview of the graphical user interfaces (GUI) of the SBNHealth Android application, is summarized in Figure 6.7. Further details on how these functionalities were implemented are elaborated throughout the next subsections, starting with the user pairing process (a patient requesting the HCP to monitor his/her data) as presented in subsection 6.7.1.1 and continuing with the rest of the vital signs monitoring functionalities as presented throughout the subsections 6.7.1.2 – 6.7.1.7.

[7] Considering that this thesis is submitted to the Information School department, the supervisory team recommended that it was better not to include technical details on the source code implementation, just the textual information on the actions and steps needed to perform the functionalities of the proposed SBNHealth prototype.

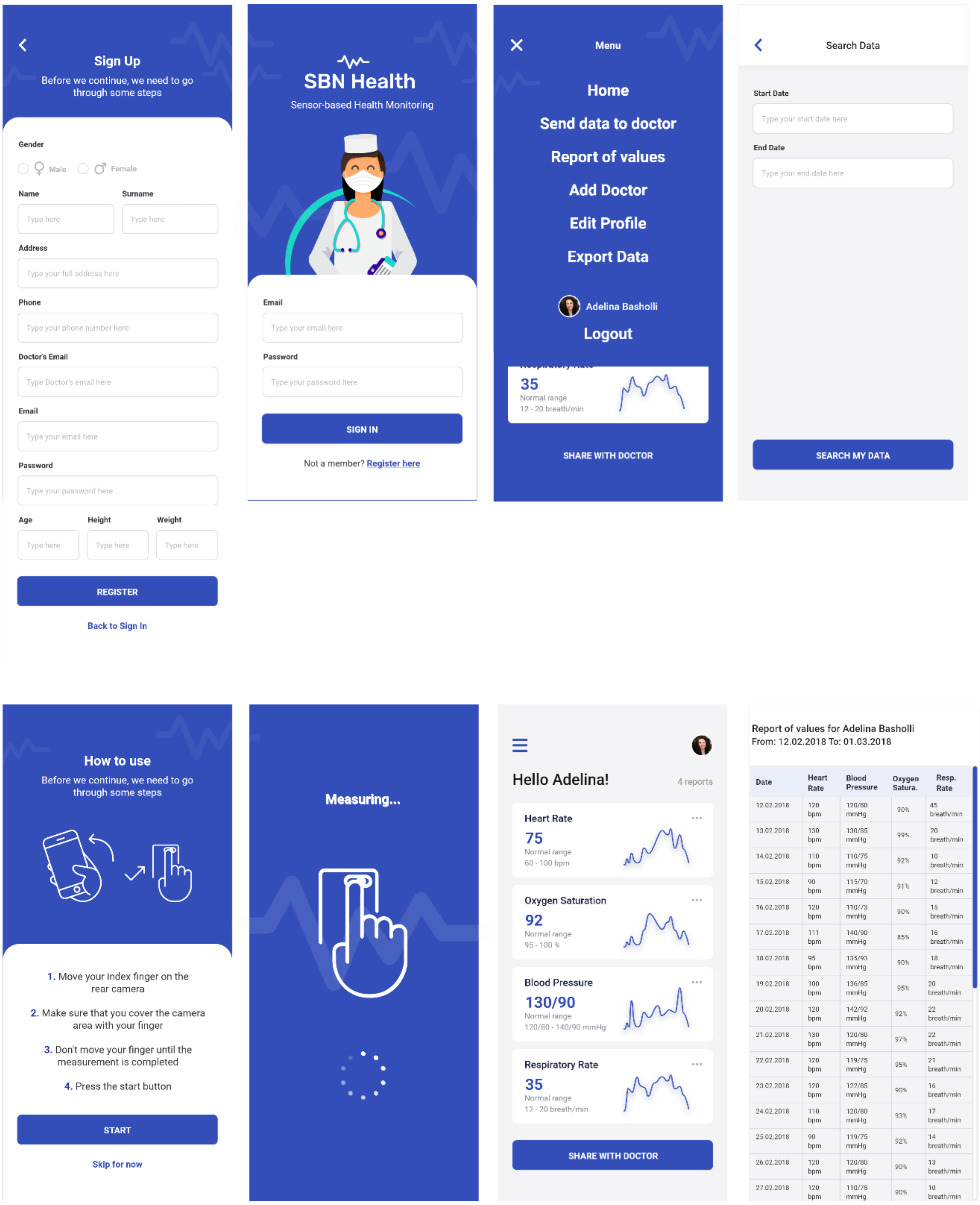


Figure 6.7 Some of the SBNHealth Android application's GUIs

Figure 6.7 presents some of the Android application's GUIs, however, the rest of the screens related to the functionalities included in the mobile application are presented in Appendix C (C.1 – C.11).

6.7.1.1 User pairing

The details on the user pairing process are as follows:

1. The patient registers using his/her personal information in the Android app (Appendix C.1):
    - The patient's email was considered a unique field; hence the mobile app did not allow two patients with the same email to be registered;

    - The patient needed to provide personal information and a doctor's email (in the design of this prototype, this study referred to a doctor, however, it can be another medical level of monitoring personnel, i.e., specialized nurse, family doctor);
    - Part of this process, in the back-end implementation of the mobile app, is also storing this patient's data transmission mode (subsection 6.4.2). This means that by default a transmission mode will be saved as *Mode 1: Patient willingness*. This can be changed later on, based on this patient's health condition, as presented in subsection 6.7.2.4.
2. Once the patient's registration process was finished successfully, then the user pairing process continued:
    - An email with the generated unique, patient random code, was sent to the doctor's email (Appendix C.7);
    - The invited doctor can *Add Patient* (Appendix D.6), using his/her unique, random code, that he/she just received on the email as presented in subsection 6.7.2.2;

Consequently, after the successful user pairing process, the monitoring doctor can see this patient's values of vital signs, contact him/her by email or phone (Appendix D.8), or change the data transmission interval (Appendix D.9). The healthcare professionals' functionalities are further elaborated in subsection 6.7.2.

6.7.1.2 Measuring vital signs

The patient on the Android mobile app, could perform measurements of his/her vital signs and see the medical condition in real-time. The graphical user interfaces of the mobile app that enabled the patient to perform measurements are included in Appendix C.3.

The Android mobile app, using the heart rate sensor of the mobile unit (in this case the mobile phone), could perform measurements and did calculations of the values for the blood pressure, respiratory rate, and oxygen saturation. The implementation details on these mathematical calculations were based on a research project named HealthWatcher (2021) that was made available for use. Hence, the mobile app used photoplethysmography (PPG) signals, that represent a technique for detecting optical volumetric changes in blood circulation. These signals were captured from the camera (as seen in Appendix C.3, the patient had to put the index finger in the rear camera), by image processing of frames of the red, green, and blue (RGB) intensities. Consequently, the patient had to hold the index finger for 30 seconds on the rear camera of the device, for the mobile app to process the frames of the RGB intensities, and perform the calculation of the values of the vital signs.

After performing the measurement, the patient could see the values of the vital signs, and underneath the current values, were included the normal range of the values for every vital sign. It is worth mentioning that the healthcare professionals, when adding a patient for monitoring (Appendix D.6, subsection 6.7.2.2) could provide information on the normal range of values for every vital sign of the specific patient. This was included in the proposed SBNHealth, according to healthcare professionals' suggestions (subsection 5.5.6.3). Nevertheless, this was left as an optional functionality, and hence, if the medical staff did not add the normal range of values, the literature-based values were used (subsection 2.3.3). The next subsection will elaborate on additional functionalities that the patient could perform with the mobile app as presented in Appendix C.10.

6.7.1.3 Sending data to the monitoring staff

After performing the measurement, the patient could choose to share it with the monitoring personnel. Nevertheless, if the data transmission mode is *Mode 2: Every two hours*, or *Mode 3: Real-time*, then the gathered sensor data, were transmitted automatically based on the predefined time frame, every two hours, or every 30 seconds for the real-time transmission. However, if the patient was on data transmission *Mode 1: Patient willingness*, then the *Share with doctor* button was visible on the screen (Appendix C.4) and the patient could select this.

When the patient is on data transmission *Mode 1: Patient willingness*, all the recorded measurements of the vital signs, were stored in the local database on the mobile unit (i.e., smartphone). They were shared with the monitoring healthcare professional(s) when the patient decided this (i.e., by selecting the *Share with doctor* button).

6.7.1.4 Generate a report of values

A patient may want to see a report of the values of the vital signs recorded for a specific interval of time. Hence, the patient could select between two dates, and a summary table of the values of the vital signs was presented, as shown in Appendix C.5.

The values of the vital signs presented in the report were rounded values for the specific date. As the patient may perform several measurements throughout the same day, and considering the limited space of the mobile phone screen, this study decided to summarize and round the average values of the vital signs per specific day.

6.7.1.5 Add another monitoring medical staff

The patient could provide access to his/her values of the vital signs to an unlimited number of medical staff. The idea after this functionality is that a patient may want to consult and share the vital signs with different medical specialists.

Hence, from the left-hand menu of the mobile app (Appendix C.10), the patient could choose to *Add a Doctor* and provide the email of the monitoring medical staff that he/she wanted to give access to his/her vital signs (Appendix C.6). In this way, the same user pairing process, as presented in subsection 6.7.1.1 was performed.

6.7.1.6 Export recorded vital signs

A very similar process as the one described in subsection 6.7.1.4, was followed if a patient wanted to generate and export a report of the vital signs for the specific interval of dates. Hence, as presented in Appendix C.9, the patient could choose the start and end date of the interval, for exporting the vital signs. After that, the report was generated and exported automatically in the .pdf format, to the downloads file of the mobile unit, locally in the device. This enabled the patient to print and have the report in the next medical visit with the healthcare professional.

6.7.2 Implementation of the web-based application

This subsection presents the implementation details of the web-based application that is supposed to be used by healthcare professionals to monitor and communicate with their remote chronically ill patients. The web-based application was implemented using various markup and programming languages, such as HTML, CSS, PHP, and Javascript. Hence, the SBNHealth web application consisted of a landing page, as presented in Appendix D.1, where the information about the platform, functionalities, and the research team details, were included. Further to this, healthcare professionals needed to create an account (Appendix D.2) to be able to log in and see the functionalities that the platform offered for remote and continuous monitoring of patients, as presented in Figure 6.8.

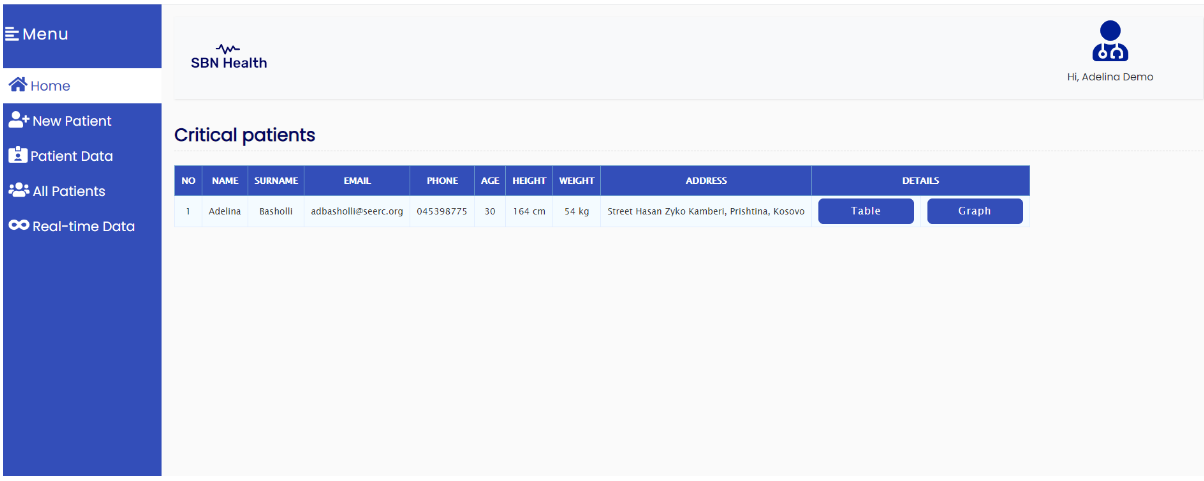


Figure 6.8 One of the SBNHealth, web-application GUI

Figure 6.8 presents one of the SBNHealth web application GUI, however, the rest of the screens related to the functionalities included there are presented in Appendix D (D.1 – D.12).

6.7.2.1 List of critical patients

The healthcare professionals during the interview study suggested having a list of patients in a more critical condition shown with priority to them. Hence, the proposed SBNHealth prototype, in the web application's Home page (Appendix D.3) included a table with the critical patient's details and the possibilities for the HCPs to contact them (email or phone) and view their values of the vital signs (table or graph).

The list of critical patients was filtered based on the values of the vital signs that were measured using the mobile unit of the SBNHealth system, as presented in subsection 6.7.1. Hence, if the average value of a vital sign (i.e., the heart rate during a day), was not within the normal range of values (e.g., 60 – 100 bpm), then the patient was listed on the Home page of the web application to attract the healthcare professional's attention to view his/her health condition.

In this case, the monitoring personnel could view the table with the patient values of the vital signs (Appendix D.4) including the date of the measurement and the average values per every vital sign that the SBNHealth offered (heart rate, oxygen saturation, blood pressure, and respiratory rate). Additionally, the SBNHealth web application enabled the monitoring medical staff to view the vital signs of a patient in a critical condition, as a graph (Appendix D.5), to compare the values at different intervals, as requested by the interviewees in the first interview study (subsection 5.5.8.6).

6.7.2.2 Add new patient for monitoring

Another functionality that the SBNHealth offered to healthcare professionals was the possibility to add a patient for monitoring (Appendix D.6). Hence, the medical personnel could add a patient that they wanted to see his/her vital signs and communicate at a distance, by having the patient unique, random code. This functionality was closely related to the user pairing process, presented in subsection 6.7.1.1. Hence, first, the patient needed to provide access to the healthcare professional for monitoring his/her vital signs, by providing the doctor's email in the mobile app, and automatically sending the email request with the unique, random code (Appendix C.7).

The healthcare professional, while adding the patient for monitoring, could additionally provide the normal range of value for every vital sign (Appendix D.7). Hence, as discussed by the participants during the interview study (subsection 5.5.6.3), the critical range of values may not be the same for all patients. Therefore, the SBNHealth web application considered this suggestion by providing the medical staff the possibility to set the normal range of values. In case the healthcare professional did not want to provide this information, SBNHealth considered the literature-based information on the normal range of value of the vital signs (subsection 2.3.3).

6.7.2.3. Patient data

The healthcare professionals could access a patient's detailed overview on the values of the vital signs for every measurement that they have performed and shared with them, through the *Patient Data* item on the left-hand menu of the SBNHealth web application (Appendix D.8). Also, in this case, to prevent unauthorized access to patient information, SBNHealth requested the healthcare professional to enter the unique patient's code.

This functionality allowed the healthcare professional to view patient information such as name and surname, phone, email, age, weight, height, and address. Furthermore, the medical staff could select the *Table* or *Graph* method to view the patient detailed values of the vital signs for every measurement taken through the mobile app.

6.7.2.4 List of all patients and their transmission modes

Similarly, on the left-hand menu of the SBNHealth web application, healthcare professionals could access the list of all their patients under monitoring (Appendix D.9) in a table format. The details of the patient such as name and surname, email, phone, age, height, and weight were included too. Further to this, the table contained the information on the data transmission mode (subsection 6.4.2). Hence, the active data transmission mode was marked with a red colour.

The healthcare professional could view a patient's vital signs, and could decide to change the data transmission mode (i.e., a patient's health condition has worsened and now the medical personnel want to monitor in real-time). The changes to data transmission mode were initiated by the healthcare professionals by choosing the transmission mode in the table of all patients (Appendix D.9). After that, a notification was sent to the patient (Appendix D.10) via the mobile app. Once the patient confirmed the data transmission change, the table was refreshed with the new transmission mode enabled, and the healthcare professional received the patient's vital signs in the agreed mode.

After the patient has agreed to be monitored in real-time, then his/her values of the vital were transmitted every 30 seconds to the web application, as discussed in the next subsection.

6.7.2.5 Real-time data monitoring

The proposed SBNHealth prototype enabled the remote monitoring of a patient in real-time. This means that the patient needed to use the mobile unit and perform measurements all the time. Then, the gathered vital signs were transmitted every 30 seconds (the time for performing a measurement as described in subsection 6.7.1.2) to the healthcare professionals.

Hence, to enable this transmission mode, the healthcare professional needed to change the data transmission mode to real-time, and the patient had to agree on this change.

6.8 Limitations of the proposed SBNHealth prototype

The proposed sensor-based prototype enabled the remote and continuous monitoring of a patient’s vital signs and distance-based communication with the healthcare professional. Nevertheless, the proposed SBNHealth prototype was implemented based on certain assumptions which lead to its limitations, as follows:

- It is the responsibility of the healthcare centre to assign the medical personnel who will provide distance-based monitoring and feedback to patients based on the data provided by the sensor-based platform. Hence, the platform did not include any verification means that the registered account corresponds to a certified and authorized medical personnel that could provide remote monitoring assistance.
- There should be a reliable Internet connection, either wireless or mobile data, to transfer sensor data from the local storage of the mobile phone to a remote server. This may cause problems in particular areas, e.g., rural areas, where Internet or mobile connectivity is limited.
- The mobile monitoring unit is assumed to work properly only when it detects the finger index of the patient and there is sufficient light to capture the RGB intensities.
- Another limitation is related to the limited memory space of the mobile monitoring unit. If patients will use only the data transmission *Mode 1: Patient willingness* for a longer time, hence saving all the data in their local mobile units, then there is a possibility for memory leaks.
- As the values of the blood pressure, oxygen saturation, and respiratory rate were calculated from the RGB intensities of the captured blood circulation images, they may not provide accurate results. Hence, the patient may not place the index finger in the right position on the rare camera, or there may not be a sufficient clear surface and view, and in this way, the values of the vital signs may not be accurately “measured” (actually calculated). Therefore, further verification of the measurement of these values is recommended.
- The proposed SBNHealth prototype did not include all of the mentioned vital signs from the healthcare professionals during the interview study, due to the hardware limitations of the mobile unit used during the implementation. Hence, the HCPs proposed to have the values of the temperature, pulse, and blood glucose too. Therefore, further research and implementation is recommended to provide also these values.
- The current version of the SBNHealth prototype does not provide alarms to healthcare professionals when a patient's condition is worsening, which was another suggestion mentioned by them during the interview study. Nonetheless, it shows the table of critical patients. This could be implemented in further developments of the system.

These limitations of the proposed sensor-based prototype may be addressed with a future implementation on the SBNHealth, by adding functionalities that will consider the HCPs' suggestions. Nevertheless, the current version of the proposed system aimed to provide HCPs a remote and monitoring prototype, for them to have an experience and be able to discuss more specifically the distance-based and real-time patient monitoring and answer this thesis research questions (subsection 2.8.3).

6.9 Conclusions

This chapter presented the design and implementation of a remote and continuous sensor-based architecture and prototype that was based on the findings of the empirical study as presented in chapter 5. The design phase followed a top-down approach, in that it started by presenting the high-level architecture that contributed to the formulation of the layered schema and the context model. The proposed model architecture presents a unique and feasible sensor-based schema, that is based on technology acceptance criteria that were evaluated before this architecture was proposed. Hence, the functionalities included in the proposed prototype were based on the health practices and the needs of the medical personnel for remote patient monitoring.

As the findings of the first interview study showed, the HCPs did not have experience with a similar remote and continuous sensor-based monitoring platform for communication with their patients. Hence, to address some research questions of this thesis (subsection 2.8.3) more specifically, and enable the participants a remote monitoring experience, a sensor-based prototype was implemented based on their needs and suggestions.

Hence, the proposed SBNHealth prototype will be used during the evaluation interview study with the same HCPs that participated also in the first round of interviews, in next chapter 7. The aim of the following chapter (7) is therefore to evaluate the proposed sensor-based prototype, as well as get feedback from the participants on the functionalities that are included in the proposed SBNHealth, and enable them a remote monitoring experience during the interviews of this study.

Chapter 7 Evaluation of the proposed SBNHealth prototype, Second interview study

7.1 Introduction

The previous chapter 6 presented the details of the design and implementation of the proposed sensor-based architecture that enabled healthcare professionals to monitor their chronically ill patients remotely and continuously. The proposed sensor-based health monitoring (SBNHealth) platform was implemented based on the findings of the first interview study with healthcare professionals (chapter 5). Hence, the evaluation phase of this research project, elaborated in this chapter, includes the same group of people that participated in the first round of interviews, as far as this was possible, given that now they performed some tasks with the implemented sensor-based platform (Appendix B.8). After the tasks with the system, HCPs were asked a group of questions related to their feedback and experience with the implemented platform (Appendix B.7).

This chapter includes detailed information on the methods, pilot phase, and results of the evaluation phase, as the second round of interviews with HCPs, on their comments and feedback regarding the proposed SBNHealth platform. This is considered as the final phase towards the proposal of a sensor-based architecture, its implementation, and an evaluation of the proposed prototype.

This chapter is organized as follows. Section 7.2 presents the aim and research questions that this evaluation phase will answer. Methods are briefly elaborated in section 7.3, considering that some details are very similar to the ones presented in chapter 5, the first interview study, as both these studies used the same research methods and research instrument as designed in chapter 4. Details on the pilot study are presented in section 7.4. All the findings that consist of major themes and their underlying sub-themes are elaborated in section 7.5. A detailed discussion of the findings of this evaluation study is presented in section 7.6. The strengths and limitations are elaborated in section 7.7. Finally, section 7.8 concludes the work and results of the evaluation phase by providing answers that address the research questions and the key findings of this interview study.

7.2 Aim and research questions

This phase aimed to get healthcare professionals' feedback, comments, and suggestions on the proposed prototype of a sensor-based platform that enabled them to monitor their chronically ill patients at a distance. As the final stage of this research project, the evaluation phase focused on the system's functionalities and their applicability to the healthcare setting. Hence, considering that HCPs during the first phase of interviews (chapter 5) did not have experience in real-time and remote communication and monitoring of their chronically ill patients, there were some aspects that they could not provide detailed feedback. Therefore, this stage of research, as participants had the chance to perform tasks with a sensor-based prototype, includes more detailed and specific research questions, which this interview study aimed to answer. Consequently, the research questions were formulated also considering the implementation of the developed SBNHealth prototype (chapter 6).

The questions that this stage of the research aimed to answer, and are aligned with the overall research questions of this thesis presented in subsection 2.8.3, were as follows:

1. To what extent would healthcare professionals apply the proposed prototype of a sensor-based platform for remote and continuous monitoring of their chronically ill patients in developing countries, Kosovo as a case study?
2. How can the proposed prototype of the sensor-based platform affect healthcare professionals' daily work and patients' life?
3. How likely is the proposed prototype to be implemented in the private and public healthcare centres of a developing country, i.e., Kosovo?
4. What may be the benefits of applying the proposed prototype of the sensor-based platform for the healthcare system of a developing country, Kosovo in this case?
5. What may be the factors that may limit the successful application of the proposed prototype of the sensor-based platform, from the healthcare professional's perspective?
6. What are healthcare professionals' suggestions to further advance the proposed prototype of the sensor-based platform?
7. What are the strengths and limitations of the proposed sensor-based prototype?

Consequently, the evaluation phase aimed to answer the above-mentioned research questions using interviews as a research instrument. Details about the methods are presented in the next section.

7.3 Methods

The methods used for this evaluation study include very similar details as described in chapters 4 and 5. Similarly, this research phase consists of a qualitative research method using interviews as a study instrument to collect information from participants. Details about the methods of this research stage that differ from the previous round of the interviews are discussed as follows.

7.3.1 Design of this interview study

This evaluation interview study followed a similar structure of processes as presented in section 4.5. Semi-structured and in-depth interviews were selected as a research instrument. Similarly, as in the first interview study (chapter 5), participants were healthcare professionals dealing with chronically ill patients, however, the recruitment procedure compared to the first interview study was a bit different and is briefly presented in subsection 7.3.2.

The interviews for this evaluation interview study were also conducted in the American Hospital in Prishtina, Kosovo (section 4.4). This research got the ethical approvals of the Research Ethics Committee within the University of Sheffield and the American Hospital in Prishtina, as presented in subsection 4.3.2.

Taking into account the aim and objectives for this evaluation study (section 7.2), the interview guide was formulated based on variables such as subjective norms (TAM2), job relevance (TAM2), perceived usefulness (TAM2), perceived ease of use (TAM2), task-technology fit (TTF), performance expectancy

(UTAUT model), social influence (UTAUT model), behavioural intention (TAM2), truth-telling (a variable that was found from the results of the first interview study as presented on chapter 5). A detailed categorization of interview questions based on TAM variables is included in Appendix B.9.

7.3.2 Recruitment

The participants of the evaluation phase were healthcare professionals who participated in the first round of the interviews as discussed in chapter 5. The same group of participants was chosen to understand their feedback and evaluation on the proposed sensor-based prototype that was implemented based on their opinions, attitudes, and needs identified during the first interview study. Nevertheless, due to the time range between the first interview study (years 2016-2017) and this evaluation interview study (year 2021), most of the participants were not working anymore in the American Hospital in Prishtina, and two of them were on maternity leave. As such, out of 26 healthcare professionals that participated in the first round of the interviews, only eight of them were currently (December 2020 - February 2021) working there.

These participants were invited to participate through the human resources (HR) department of the American Hospital in Prishtina. The recruiting procedure was based on purposive sampling. Purposive sampling was used to ensure that HCPs that deal with chronic diseases and who had participated in the first research study, were interviewed. All participants were asked verbally to take part in the study.

7.3.3 Interviewing process

Interviews for the evaluation phase of this research project were conducted within the premises of the American Hospital of Prishtina and during the healthcare professionals' working schedule. The interviewing process started on the 25th of January 2021 and ended on 21st February 2021. During this period of time, eight interviews were conducted and transcribed in Albanian and then translated into English. Each participant was given an Information Sheet and was explained in detail the idea of the study. If the participant confirmed to participate in the interviewing process, then the consent form was signed. All the interviews were recorded for transcription purposes. Before the interviews, participants filled a demographic questionnaire (Appendix B.6). which did not reveal their identity and then continued with the list of tasks (Appendix B.8) that they were asked to perform with the SBNHealth prototype. A laptop was used to do the demonstration, which had the SBNHealth system opened in a web-link. Participants used the list of tasks, which included details on the functionalities that they needed to perform with the system.

Every participant was asked to perform some predefined tasks with the proposed sensor-based prototype and after that, an interview guide (Appendix B.7) was used to discuss the healthcare professional's experiences with the system. At the end of every interview, a group of questions regarding the interviewing process, were discussed with every participant as part of the pilot study. For interviews 4 and 6, as shown in Table 7.1, there was no time for the pilot study questions as patients were waiting for the participants; therefore, the interview focused only on this study's main questions due to the time restrictions.

Table 7.1. The timeline of the interviews

Interview	Profile	Tasks with the system (hh:mm:ss)	Interviews questions (hh:mm:ss)	Pilot study questions (hh:mm:ss)	Total length (hh:mm:ss)
Interview 1	Doctor	00:19:05	00:23:27	00:02:00	00:44:32
Interview 2	Nurse	00:17:29	01:15:03	00:01:09	01:33:41
Interview 3	Nurse	00:22:00	00:28:00	00:01:03	00:51:03
Interview 4	Doctor	00:04:05	00:14:76	00:00:00	00:19:26
Interview 5	Doctor	00:12:02	00:34:74	00:01:24	00:48:18
Interview 6	Doctor	00:08:16	00:12:22	00:00:00	00:20:38
Interview 7	Nurse	00:13:02	00:21:08	00:01:08	00:36:08
Interview 8	Nurse	00:14:01	00:25:31	00:01:11	00:40:12
Mean		0:13:45	0:29:30	00:07:55	0:44:15

As shown in Table 7.1, the interviews for the evaluation phase consisted of 354 minutes of recordings (mean = 44 minutes) per interview. The mean time for performing the tasks with the system was 14 minutes and another 29 minutes for the interview questions (excluding the pilot study questions).

7.4 Pilot Study

At the end of every interview with the healthcare professionals, there were a specific group of questions that they were asked as part of the pilot study. These questions included details about the tasks that HCPs performed with the system, questions related to the interviewing process, and similar information to help this study test and evaluate the research instrument and its design, as presented in Table 7.2.

Table 7.2 Evaluation questions for the pilot phase

Tasks performed with the system
1. How did you find the tasks performed with the system? a). Were they clear? b). Do you think you needed additional information on how to perform the tasks? c). Were all the details of the system covered through the predefined tasks?
Interview questions
2. How did you find the interview questions? a). Were they clear? b). Do you think you needed more information on the questions of this interview study?

Interviewing process
3. How would you evaluate the interviewing process? a). Did it take too long? b). Was it clear and structured? c). Is there something that you would suggest to us for consideration in other interviews?

These questions were discussed with six participants (out of eight, as elaborate in subsection 7.3.2, due to participant's time restrictions) and all of them agreed that the tasks and interview questions were clear to them and they did not need additional help or information on them. Furthermore, the participants did not suggest something to consider in the consequent interviews that were undertaken by that time.

The pilot study contained also questions related to the length of the interviewing process. Considering that the interviews were recorded during the healthcare professional's working schedule and it took them approximately 44 minutes of their time, it was important to understand their opinions on this process, and if they needed to be shortened. However, also in this regard, they had positive comments, as below:

> *"No (laughs) because thankfully I did not have much work today." (Interview 2. Nurse)*
>
> *"(laughs) for me .. I had time, so it was not a problem." (Interview 5. Doctor)*
>
> *"No (2s) it took me some time but as I accepted, I considered it. You also informed me in advance that this [interview] could take time. So, it was everything according to what you informed me." (Interview 3. Nurse)*
>
> *"No, it was a pleasure." (Interview 7. Nurse)*

In this way, no changes were made to the interview guide questions or the interviewing process. The following section presents the results of this interview study.

7.5 Results

This section will provide detailed information on the results of the second round of the interviews, this time for evaluating the proposed sensor-based platform. The findings are categorized into themes and sub-themes and discussed in detail in the following subsections.

7.5.1 Sample characteristics

This study used a demographic questionnaire to understand participants' related profile information and their experience with digital technologies for remotely communicating or monitoring their patients. The participants were eight healthcare professionals, four doctors, and four nurses, and they were four males and four females. Of these participants, four of them were also working in the public healthcare centre, the UCCK. This helped us understand their perspectives from two different institutions.

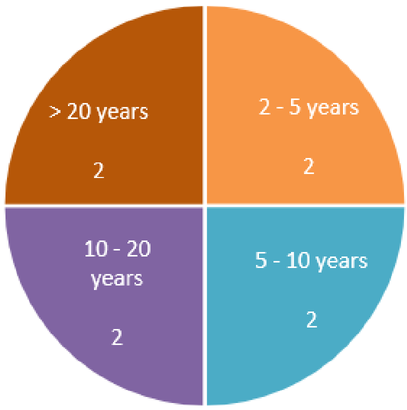


Figure 7.1 Frequency of length of work experience for the interviewees

As shown in Figure 7.1, this evaluation study had two participants in each group of years of experience. Participants, therefore, had different working experiences, ranging from 2 to 5 years up to those who had more than 20 years of experience as healthcare professionals.

All participants confirmed to use digital technology daily, including their mobile phones, PC or laptops. Further to this, three participants confirmed that they had experience in communicating with patients at a distance and reading values of vital signs that their patients were sending to them through phone (for example applications such as Viber™ or WhatsApp™).

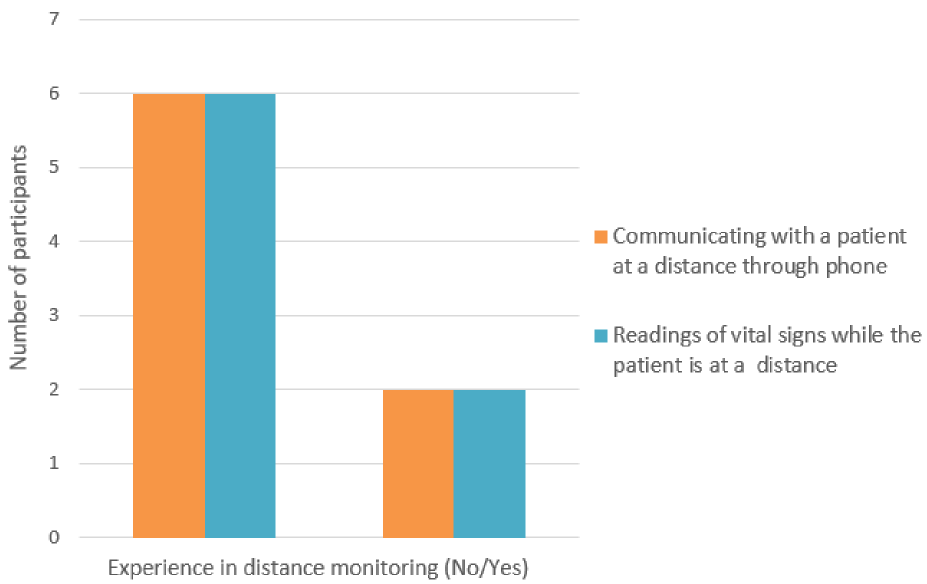


Figure 7.2 Experience of healthcare professionals in monitoring or communicating with patients at a distance (NB: participants could choose more than one option)

As shown in Figure 7.2, two doctors mentioned patient monitoring through Holter monitors and a nurse that mentioned mobile applications that patients were sending vital signs to her.

This subsection presented details on the sample characteristics for this interview study. Hence, the following subsections elaborate in detail the results of the themes and sub-themes that emerged from the data analysis.

7.5.2 Findings of the evaluation interview study

As presented in Figure 7.3, the evaluation study identified nine major themes and their corresponding sub-themes, that provide detailed information on the investigated phenomena, and aim to address the research questions of this study (section 7.2).

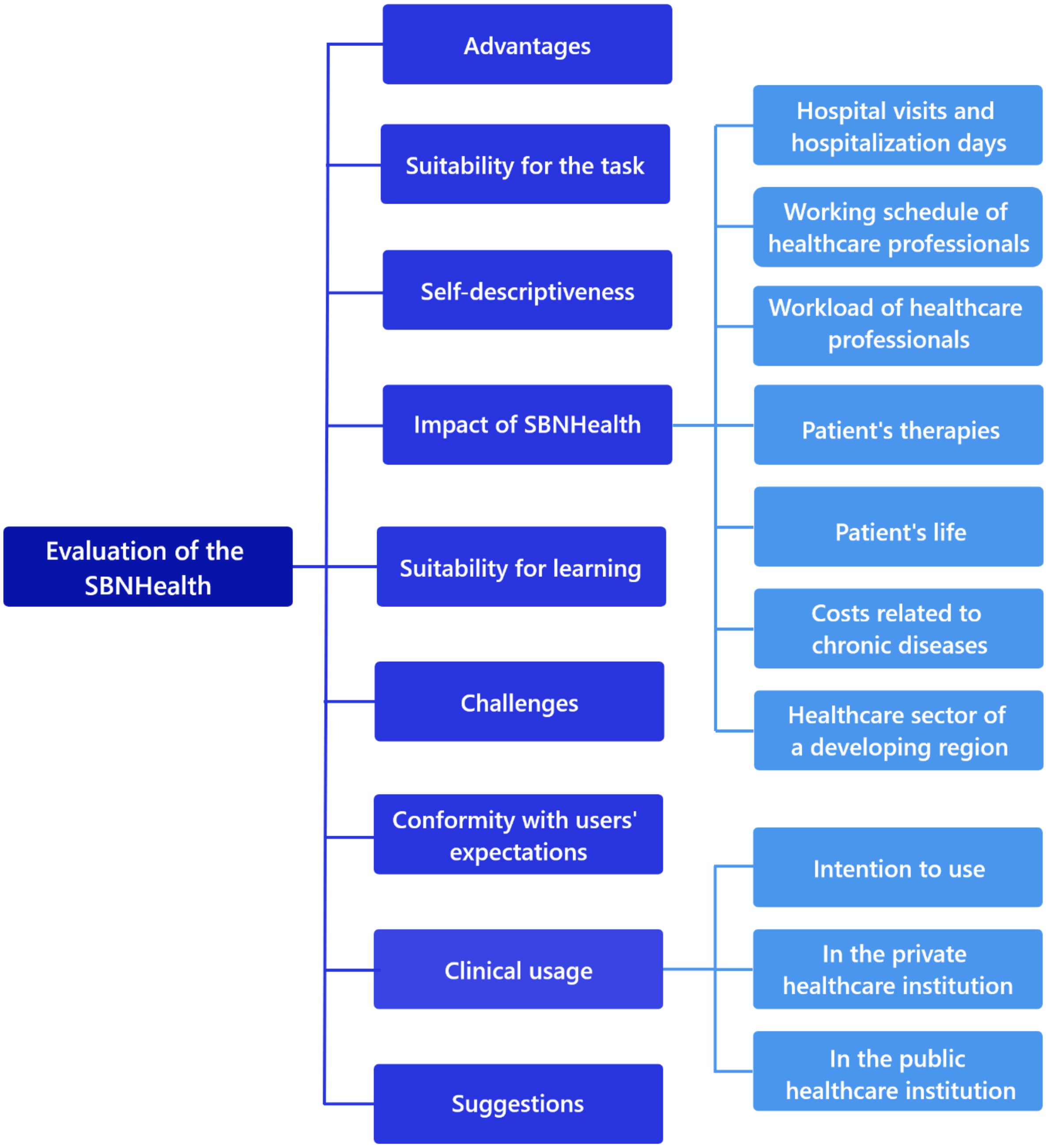


Figure 7.3 Themes and underlying sub-themes of this evaluation study

These major themes presented in Figure 7.3, discuss the advantages of the proposed SBNHealth prototype, the challenges that should be considered for a successful implementation, the impact of the SBNHealth in various aspects related to healthcare professionals' work, the patient's life, the costs associated with chronic diseases; the clinical usage of the proposed sensor-based platform, the self-descriptiveness, suitability for the task, suitability for learning, conformity with healthcare professionals' expectations and additional suggestions that were proposed after using the SBNHealth prototype. All these themes are elaborated in the following subsections.

7.5.3 Advantages

After performing the tasks with the SBNHealth prototype, healthcare professionals described several benefits of using this tool for remote and continuous monitoring of their chronically ill patients. They considered the proposed sensor-based platform as:

> *"A useful tool for remote monitoring of patients with chronic diseases. These existing parameters, they are the ones that help us, are useful to us. In my opinion, such a system is very useful. Not a little, but very useful, and very easy to apply, and very little time is lost from both the doctor and the patient with this platform [SBNHealth]." (Interview 5. Doctor)*

> *"It would be great to monitor the patient at a distance. It also depends on the patient's condition because there are patients who are acute cases. In these acute cases, we need to approach them more urgently. When the cases are chronic, these methods can also be used [remote monitoring]." (Interview 8. Nurse)*

Healthcare professionals confirmed that there are patients who make frequent visits, even for simpler things such as measuring blood pressure, to find out about therapy changes, and similar. Hence, having the remote sensor-based platform would enable them to communicate at a distance with their monitoring medical staff and in this way would avoid these travelling and frequent visits which affect also the cost of treating and managing the chronic condition(s) for the patient, as below opinions also suggested:

> *"With this system [SBNHealth] there is no need to make frequent visits. There are many times that the patient comes just for blood pressure, or for an ECG. So, the number of visits is reduced." (Interview 2. Nurse)*

> *"I mean here, in the clinic, would come patients who need hospitalization and not all of them. Often patients are coming - I am not feeling well, just for blood pressure – [patient's words]. It would reduce time; it would reduce the time for both the patient and the staff." (Interview 3. Nurse)*

> *"This is where the cost changes. The cost would also get affected. Because it is different when the patient has to visit, check-ups, get dressed, take the road. So, it's time and the financial side." (Interview 5. Doctor)*

While discussing the frequent visits, participants also mentioned the pandemic situation with Covid-19 and how the SBNHealth would have helped them to avoid patients in the clinic for these types of minor consultations or measurement of the vital signs.

> *"It would reduce the number of patients in the clinics, especially in the situation that we are facing now, pandemics. They would have received the remote service, the remote consultations." (Interview 3. Nurse)*

"If we consider the Covid period, from 24 hours, I have spent 5-6 hours on the phone consulting with different patients while they were at home and asking them how is saturation, how is blood pressure, so changes which were caused by Covid. On the other hand, the patient has to place the pulse oximeter, take the measurement, call me back and show me the value. I mean this system [SBNHealth], in the circumstances we are in now, pandemic time, it would be perfect. Reasonable. It would be a great help." (Interview 5. Doctor)

Most of the participants agreed that the advantages of using the SBNHealth platform for remote monitoring would be mutual for the doctor and the patient:

".. the beneficiary of this [SBNHealth] is the patient. Maybe when the patient comes to visit me, he/she has these printed or scanned vital signs values, then I can create comfort to be more punctual in his/her treatment, and it will facilitate my work and I will thank him/her." (Interview 3. Doctor)

"Everything is for the benefit of the patient. It enables the patient to easily manage his/her disease. Also, it offers better support to him/her." (Interview 7. Nurse)

"The advantage, in this case, is the access to vital signs through the computer. It is very easy for us. I think it's a relief for us, not a burden." (Interview 8. Nurse)

As a doctor with more than 20 years of experience also mentioned:

"Well .. this in my opinion has some advantages compared to the patient who has to come to visit the doctor all the time. So, it shortens the time for both the patient and the doctor. Second, the patient is under continuous monitoring, which means the doctor sees him/her. Perhaps some cases are more problematic [patients in more critical condition], which need to be constantly monitored for therapy changes or something similar. When the patient is at home and uses regular therapy, then this system [SBNHealth] for me would be very useful. Even for medications." (Interview 5. Doctor)

However, the successful application of a remote monitoring platform, besides its advantages, would also depend on patient's willingness to use it, as suggested:

"It also depends on the patient how he/she is, how communicative he/she is because some patients do not tolerate much. They are not easily accessible and they are more .. more aggressive, more severe because the disease itself is a burden for patients, it makes them more nervous, more anxious. But I believe that through this system [SBNHealth] we will be able to see them easier. This way of seeing them over the phone was very simple, very good." (Interview 8. Nurse)

The advantages of applying the proposed prototype covered various aspects of monitoring chronically ill patients. Hence, the participants mentioned several advantages, such as continuous monitoring, a reduced number of visits, its application may affect the therapy of the patients, it may avoid unnecessary phone calls, and may limit travelling time and related expenses. However, most of these factors were from an individual's point of view, either the medical staff or for the benefit of the patient. Hence, the following subsection presents another aspect of the evaluation of the SBNHealth for clinical usage inside the public or private healthcare institutions.

7.5.4 Clinical usage

This subsection presents the findings of this study on the actual usage of a sensor-based platform from the clinical perspective. Hence, also from the results of the first interview study (subsection 5.5.3), it was apparent that HCPs were using some wired-based digital systems even for remote patients. These results were also confirmed in the second round of interviews:

> *"Look, we do remote monitoring in patients with device therapy. Patients who have a pacemaker. They [patients] come from time to time and we do battery programming. However, the companies in question that have these products, for example, Medtronic and similar, also allow remote monitoring. Monitoring the parameters of their device and I have such experiences, however for a specific device." (Interview 1. Doctor)*

Healthcare professionals were also providing some consultations to patients that were contacting them through various applications such as Viber™ or WhatsApp™. The patients were sending vital signs or consulting with the medical staff about their health condition, for example:

> *"Only sometimes when the patient calls to the clinic when someone at home measures his/her values [the vital signs] and says - I have this blood pressure, what would you recommend to me, what to get as medication, what to do [patient's words]." (Interview 2. Nurse)*

> *".. except for communication through applications such as Viber™, WhatsApp™, when the patient has our phone number and we exchanged messages. Simply what the patient has noted and not that we monitored or saw them with sensors." (Interview 3. Nurse)*

However, participants confirmed that they did not have a similar experience with using a remote and continuous sensor-based monitoring platform for their patients at a distance.

> *"No, except the demos at various workshops, I have not seen another similar sensor-based platform. There are no such systems in Kosovo." (Interview 4. Doctor)*

> *"Similar systems, no. The closest that is approaching this is for example Samsung Health, which has more or less the same mechanism, finger placement, and parameter measurement. But it is not something that the doctor connects with the patient online. So practically we do not have such experience." (Interview 6. Doctor)*

> *"Oh, these systems .. will never come to our country, too good to be true (laughs). We are very far away." (Interview 7. Nurse)*

> *"No. We did not have such a system for remote monitoring." (Interview 8. Nurse)*

Nevertheless, the healthcare professionals were willing to have a remote and continuous sensor-based monitoring platform also for clinical use and this was also described from them with actual use case scenarios on how they would have worked with such a platform if it would have been implemented in their clinic:

> *"If I can imagine it then … it seems to me to be very applicable to several specific patients we have. Especially the group of patients who are chronic and with a slightly more fragile, or a critical condition, whom we need to have an eye on. It seems a platform [SBNHealth] ... not to say relatively, but very good, as long as we can, in real-time, get these vital parameters of the specific, critical condition, patient, so that we have access to their current state through the parameters that the platform offers. Hence, it seems to me that it is a .. system that a healthcare professional would like to have, the monitoring doctor of the patient." (Interview 1. Doctor)*

> *"For example, I can log in if I have a patient monitoring remotely and see the values of the vital parameters." (Interview 2. Nurse)*

Considering these use case scenarios, this evaluation study wanted to further investigate other aspects as presented in Figure 7.4, related to the clinical usage of the remote and continuous monitoring platforms such as the proposed sensor-based prototype.

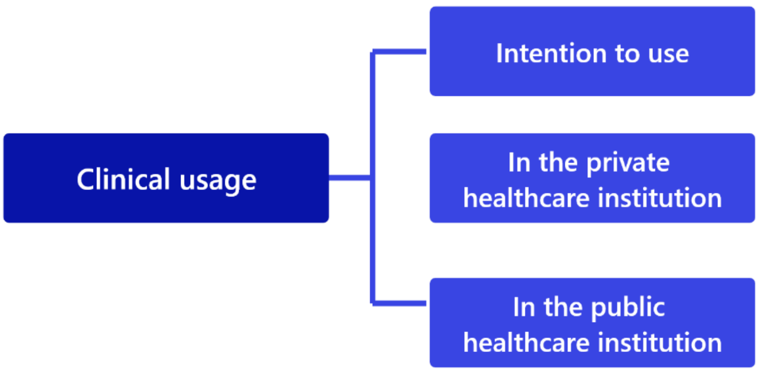


Figure 7.4 Underlying sub-themes of the clinical usage of the proposed sensor-based prototype

As presented in Figure 7.4, the following subsections will provide more details in three aspects of clinical usage of the proposed SBNHealth prototype. Hence, the healthcare professional's intention to use a remote and continuous sensor-based platform such as the SBNHealth prototype, and the platform application in the private and public healthcare institutions according to participants' point of view.

7.5.4.1 Intention to use from the medical staff

Healthcare professionals confirmed not to have experience with monitoring chronically ill patients remotely and continuously using sensor-based technology. Hence, after using the SBNHealth prototype it was important to understand their experiences and attitudes on real-time monitoring and communication with a distance-based patient. This means that this study investigated HCPs' intention to use a similar platform if it was proposed as an application in their health institution.

Findings of this evaluation phase on the intention to use a similar sensor-based platform for remote and continuous monitoring, revealed some positive aspects and attitudes of participants to apply it for monitoring of their chronically ill patients, as they also confirmed:

"For me, it would be very good to work with this system .. since I consider it to be easier and not everyone .. because we now know the history of the patient, and not everyone needs to make visits to the clinic. Because even the nurse now knows the patient's condition. So even the nurse understands if the value of a heart rate is at a normal range or not." (Interview 2. Nurse)

"I would work with such a platform [SBNHealth]." (Interview 3. Nurse)

"But I like this [SBNHealth] because I, at least as a doctor who is getting older in medicine [more than 20 years of experience], for every case that I have, every patient, I want to follow him/her as it remains in my head because after he/she is discharged from the hospital and I want to know how he/she is, how his/her situation is." (Interview 5. Doctor)

"Yes, I believe, I would use it [the SBNHealth]." (Interview 7. Nurse)

These were the personal opinions of the healthcare professionals on their intention to use a remote and continuous sensor-based platform, such as the SBNHealth prototype, that they performed tasks with. However, it is important to consider their opinions about the application of such a monitoring system from the institution's point of view. In this context, this study investigated the clinical application of SBNHealth from two perspectives, the private and the public healthcare institutions.

7.5.4.2 Perspective of the private healthcare institution

The findings on the clinical usage of a sensor-based prototype for remote and continuous monitoring of chronically ill patients for a private healthcare institution revealed different and important aspects that system developers should consider. Hence, the healthcare professionals confirmed that such a system would be possible to apply in their private clinic, for example:

"I believe there is no reason not to apply. For example, in institutions where there is internet access, we are now talking about the American hospital that has good internet on computers and everywhere; why not have such access [referring to access on the SBNHealth]." (Interview 6. Doctor)

"For this clinic, I believe it can be applied." (Interview 7. Nurse)

"Yes, it can be applied." (Interview 8. Nurse)

Further supporting their confirmation, some participants suggested that the proposed prototype should be used by a group of patients that the medical staff wants to keep an eye on, for example, those who are in a critical or unstable condition (e.g., had surgery, were recently discharged from the hospital, have values of vital signs that fluctuate very often), for example:

"Yes it would be good since we have chronic patients here .. normally they should be here after they place a stent and not everything ends there. They always have routine visits ... there are some [patients] that we discharge from the hospital, but they may still not have stable blood pressure and in this way, we have to monitor them. It would work very well if we would also have this system [SBNHealth]." (Interview 2. Nurse)

"It would be possible, but for a limited number of patients. Not all patients. For example, monitoring the situation after the intervention, yes, it would be possible. If a patient had surgery today and after two days goes home and within a week it would be good for any of the staff to monitor the patient. The patient may be fine for 2 days, but within a week there may be a change in the condition. So, monitoring after the intervention [the surgical procedure] I believe would be a good thing." (Interview 3. Nurse)

"When you have this tracking [SBNHealth] you feel much comfortable because you also have monitoring from work or home. You always have information on how his/her condition is going. For this reason, it would be useful for the hospital to have such a system [the SBNHealth]. As a system, I like it a lot. I think it could especially affect the complications that can appear after health problems. This is also very good information in the relationship between the hospital or the doctor and patient." (Interview 5. Doctor)

Nevertheless, there was also one participant who discussed the financial impact of using the proposed sensor-based prototype for the private healthcare institutions, as explained:

"And currently in Kosovo, even the medical staff are not interested in having such things. I do not believe that such a system would get implemented in a private clinic. They [private healthcare institutions] like to get bound with the patient [have the patient physically at the clinic]. It's a bad mentality here because it's a matter of payments. I mean who makes the payment. Who pays me to monitor?" (Interview 4. Doctor)

The financial aspect of remote monitoring was thus identified as a challenge for the successful implementation of the proposed sensor-based prototype and this is elaborated in further detail in subsection 7.5.6.

Regarding the application of the proposed sensor-based platform in the private clinic, six out of the eight participants confirmed that a similar prototype may be applicable also for their private healthcare centre, one of them had uncertainties as he needed to see the system's implementation and deployment inside the clinic to provide an answer and the other participant who doubted the successful implementation due to financial support (as in the above comment). Hence, the majority of the participants thought the proposal of a similar sensor-based system, such as the SBNHealth, that they performed tasks with, would also be supported for use from the private institutions. Furthermore, participants were asked whether other colleagues working in private institutions would use such a system, and they believed that the majority of them would use it, for example:

"I believe yes, they would use it." (Interview 2. Nurse)

"These changes or innovations are sometimes a problem to be implemented in the same way by all the people, even doctors. However, I believe that the majority will gladly accept it." (Interview 5. Doctor)

"Yes. Yes, of course. It's the best way, I'm thinking, it's the best way for both patients and medical staff." (Interview 8. Nurse)

This was considered to be positive feedback, given that this qualitative study involved participants with several years of working experience in both private and public institutions. Nevertheless, this study also investigated healthcare professionals' opinions on the clinical application of the proposed sensor-based prototype for the public healthcare institution separately as presented in the following subsection.

7.5.4.3 Perspective of the public healthcare institution (UCCK)

The interviews for the evaluation phase were conducted in a private healthcare institution, hence when asking participants for their opinions of the clinical application of the proposed sensor-based prototype for the public healthcare institution, some of them had no idea, for example:

> *"I don't know." (Interview 1. Doctor)*

> *"Hm ... I do not know ... in the public hospital, since we do not work there and do not know the system they have. But here, since we are in the American hospital, I know the system, and I can tell more accurately." (Interview 8. Nurse)*

However, some participants had experience also in the public healthcare centre, the UCCK, and were able to understand and provide feedback on whether the proposed sensor-based prototype could be applied in the public healthcare centre too, as explained below:

> *"I believe so .. because it is not requiring a lot of resources. Yes, they could. It could work in every home and institution." (Interview 2. Nurse)*

> *"I believe it would be a good idea to apply ... for some departments. Because I said that for some departments it is impossible to work remotely without having the patient physically present." (Interview 3. Nurse)*

> *"Absolutely. These parameters that the system has, as vital parameters that we call for a patient; these in any health service are welcome." (Interview 5. Doctor)*

From the technical aspect, during the implementation process the system designers should consider and evaluate the internet access for the public clinics, as suggested also by a healthcare professional that works there too:

> *"For public clinics, it can be more problematic because often internet access is limited to certain parts of the clinics, but I do not think that ... if it is for the benefit of someone's work, I do not know why there would be resistance to use when it facilitates the work of the doctor." (Interview 6. Doctor)*

Another important aspect that needs attention for public healthcare centres, considering their increased number of patients, is related to the limited number of medical staff to monitor patients also remotely as these participants also discussed:

"I do not know. The problem I think ... the patient I think should have a specific doctor [monitoring staff], for example as a family doctor, or as a personal doctor, as in this way as it is now, it may be a problem to monitor in the public hospital." (Interview 7. Nurse)

"I believe no. There has to be a liaison centre, so the state should have an interest and assign some caregivers to monitor these patients." (Interview 4. Doctor)

The findings of the clinical application of the proposed sensor-based prototype for the public healthcare institution, showed that there may be possible to have such platforms however, there were some important challenges that have to be resolved.

7.5.4.4 Summary

The healthcare professionals confirmed again that they had a remote monitoring experience with some digital devices for a shorter time (i.e., Holter monitors for 24, 48, or 72 hours). However, they did not have remote and continuous access to a patient's vital signs through the devices they applied to their chronically ill patients. Hene, after performing the tasks with the proposed sensor-based prototype (i.e., the SBNHealth), the participants declared not to have a similar experience with monitoring and communicating with a patient at a distance and reading his/her vital signs remotely. However, they were willing to have such a system for specific groups of patients, for example, for those in a critical condition or those whom the doctor wanted to monitor over a longer period of time.

The findings of this evaluation phase on the intention to use the proposed sensor-based platform for remote and continuous monitoring revealed the positive attitude of most of the participants (six out of eight) to apply it. Further to this, they also thought that their colleagues would use such a platform.

Regarding the clinical usage of a sensor-based prototype for remote and continuous monitoring of chronically ill patients for a private healthcare institution, such as the American Hospital of Kosovo where this study was conducted, there were different and important aspects that system developers should consider. The healthcare professionals thought that a platform like the SBNHealth could be applied in their healthcare institution considering also the infrastructure available there and the need to monitor patients remotely. However, there was also another doctor who raised the issue of the financial support for the private institutions for offering the remote monitoring of patients, as this may affect the incomes of the clinic (i.e., a reduced number of visits in the clinic, better monitoring that may lead to fewer hospitalizations, etc.). For the public healthcare institutions, on the other hand, the successful application of the proposed sensor-based prototype may be challenged by the limited internet access in some departments of the UCCK, as the participants confirmed, and the limited number of medical staff to provide remote monitoring.

7.5.5 Impact

Considering the findings on the intention to use and the applicability of the proposed sensor-based prototype in their clinic, it is important to also consider the impact of the real implementation of a remote and continuous platform on HCPs' working schedule, workload, the prescription of therapies or the impact in the healthcare sector of a developing country, such as Kosovo. Furthermore, there were also other aspects related to patients, for example, how the application of the proposed SBNHealth would affect the number of visits, or the hospitalization days, the psychological aspect of having access to his/her vital signs, and similar details that are elaborated through sub-themes as shown in Figure 7.5.

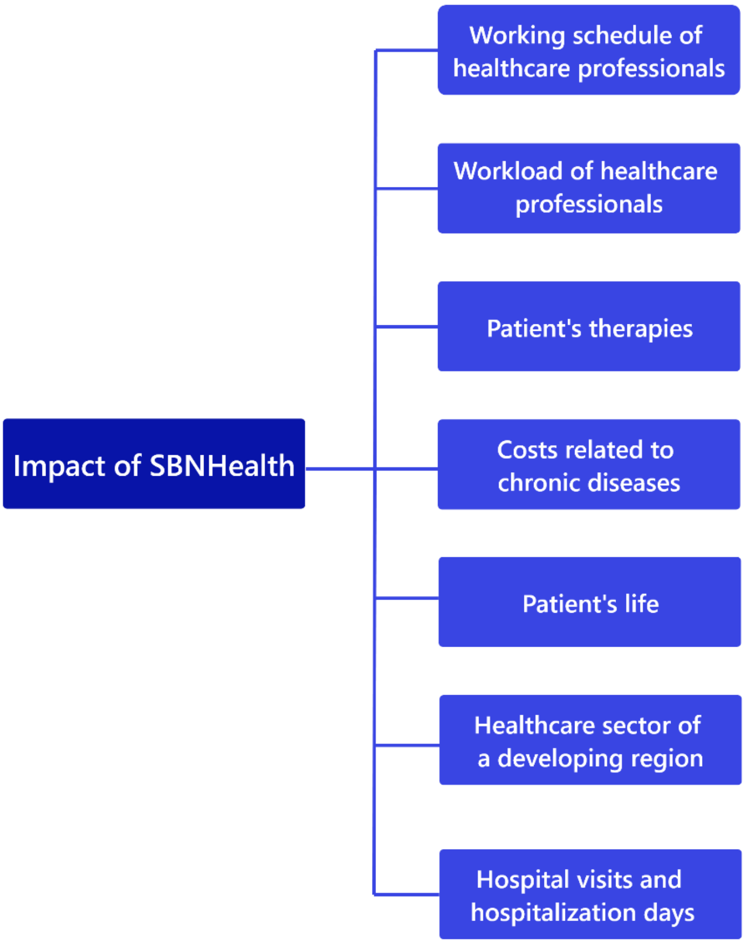


Figure 7.5 Underlying sub-themes of the impact of the proposed sensor-based prototype

As seen in Figure 7.5, the data analysis of this interview study helped to identify the sub-themes that relate to the impact of the prototype on HCPs' work, the impact on patients' life and the impact on healthcare provision aspect at the national level of a developing country such as Kosovo. Details on each sub-theme are elaborated in the following subsections.

7.5.5.1 Working schedule of healthcare professionals

When investigating the impact that the proposed sensor-based prototype may have on HCPs' working schedules, there were interesting findings, especially considering that the participants only had a few minutes of experience for performing the tasks with the system. According to the participants' feedback, the proposed prototype seemed not to take a lot of time to view a patient's vital signs and communicate with those who are in critical condition, for example:

> *"It does not seem to me that there are any extra hours that a person should share." (Interview 6. Doctor)*

> *"The usage of the system felt not to take a lot of time, it seemed effective, you have an idea about the vital parameters you are interested in and I believe it probably will not be a problem." (Interview 1. Doctor)*

Participants further proposed that there should be corresponding medical staff who would specifically monitor patients at a distance. According to them, this could be arranged between the existing HCPs internally, so that there may be a group of personnel working with shifts to offer 24-hour monitoring to the patients registered there through the SBNHealth, for example:

> *"For this, I told you that normally when working remotely you have to be online 24h to monitor the situation. You cannot monitor the situation only during regular working hours. But I believe that for example .. a part of the staff is selected, for example, 2-3 people, or 4, who monitor them [patients] on a regular schedule. For example, I start from 08 in the morning until 16, from 16-24 someone else, 24-08 another person." (Interview 3. Nurse)*

> *"Now, maybe this should be planned so that there is a time arranged when the medical staff monitors patients remotely. Or for example, by sharing time with a colleague, one person monitors other people in the clinic, while the other monitors the values of patients who are at home. So, then a kind of work-life balance would be possible. I think it is good to schedule a time or some kind of agreement with management or colleagues for better management of all patients." (Interview 7. Nurse)*

These suggestions further support the willingness of HCPs to have a sensor-based platform and also to monitor their chronically ill patients remotely. Their feedback that the usage of the platform may take them only a few minutes to have a look at their patient's vital signs, provided further positive evaluation for the proposed SBNHealth, considering the HCPs' workload. Nevertheless, as pointed out also by participants, this should be regulated and agreed with the management of the clinic and the colleagues. Details about the impact of the proposed sensor-based prototype on HCPs' workload are presented in the following subsection.

7.5.5.2 Workload of healthcare professionals

Healthcare professionals saw the part of the system where they could log in and see patients' vital signs, communicate with them either through phone or email, and send notifications to patients. Considering these functionalities that the SBNHealth offered, they evaluated the load that may affect their work. Hence, the findings in this context showed that healthcare professionals generally could allocate some minutes to monitor chronically ill patients remotely as this task did not seem to overload them, as confirmed:

> *"I do not think it would overload us. No." (Interview 2. Nurse)*

> *"If I have this laptop here and I enter a patient's code and see the last week's values, have a look at 4-5 parameters, nor 1 min time and it's done. It does not seem to me that there is an extra obligation in our daily work." (Interview 6. Doctor)*

> *"Hm no, because I saw the system. This monitoring work can take a doctor 10-15 minutes to log into the system and see critical patients. When he has time, he looks at all the patients he has on the list." (Interview 5. Doctor)*

> *"I do not think so. No. I do not think it is a burden for us. I think it's a relief for us, as the data is stored and then viewed, you can access them." (Interview 8. Nurse)*

A nurse emphasized that if a team of medical staff would be appointed to manage the monitoring of remote patients, that may not be considered a load. However, for a single person to have an eye on the patient for a longer period of time, as she mentioned, for 24 hours, it may be an additional load, as explained:

> *"If there would be a regular monitoring order within the staff members and their schedule, not just by one person, but to be a team, then I do not believe it would be a problem. However, if the same person has to monitor 24h, it is obvious that it would be a load." (Interview 3. Nurse)*

Further to this, another nurse confirmed that monitoring patients remotely could be considered similar work to monitoring in the clinic with the wired-digital system that they currently had:

> *"Hmm .. no. I would consider this as extra work. Because it's the same as when the monitoring staff comes to work, but now he sits at the computer and sees the patient there too. So, this is the same work." (Interview 7. Nurse)*

Having the majority of participants (six out of eight) confirming that the proposed SBNHealth did not seem to overload them considering the regular obligations that they have, presents a promising result for positive evaluation and could possibly lead to a successful implementation of the proposed sensor-based platform. As well as the HCPs' aspects that were discussed until now, the working schedule and workload, this evaluation study also investigated the impact of the proposed SBNHealth platform on the prescription of therapies for chronically ill patients who were at a distance. Details about these findings are elaborated in the following subsection.

7.5.5.3 Patient's therapies

The proposed sensor-based prototype enabled HCPs to view patients' vital signs for various time intervals, they could choose to view the values as average numbers per day or have them as single entries as they were recorded within minutes and seconds. Furthermore, the patient could download a report of his/her measurements for a time interval that he/she chose. Hence, considering these functionalities, the HCPs were asked whether the application of SBNHealth would affect the prescription of therapies for their chronically ill patients who were at a distance.

Generally, the findings showed a diversity of opinions among the healthcare professionals. Some of them confirmed that the application of remote and continuous monitoring through the proposed SBNHealth prototype would affect the therapies of patients, considering that currently, they could access a history of measurements of the patient's vital signs, for example:

> *"It affects a lot." (Interview 4. Doctor)*

> *"Of course, it also affects the patient's therapy. It affects all concerns of the patient because now the way of treatment will change. So, in this regard, it is a very big advantage." (Interview 5. Doctor)*

> *"It also indirectly affects the therapy, because you decide the therapy based on the values. Earlier I took the example, the patient is reporting headaches, I am seeing them in the*

evening, there has been the same headache, I would increase the dose, there has been improvement, we continue the same dose, there has been a deterioration, we change the therapy. For this reason, it will also be useful in this regard." (Interview 6. Doctor)

Some important factors need consideration and may limit the prescription of therapies electronically. According to the participants, this may depend on the patient's condition, for example:

- critical patient with fluctuating values of vital signs;

  "It depends on the patient's condition." (Interview 3. Nurse)

  "With some patients, you can agree and you can intervene even remotely with the therapeutic approach, with the therapy they have at home, for example, you can tell them: Change this, do not take this today. While in other cases, it would be good that based on the condition, based on the actual parameters, you would have an idea that in the specific condition you cannot intervene with distance-based measures and it would be good to invite the patient for a check-up in the clinic." (Interview 1. Doctor)

- type of the therapy, for example for venous therapy this may not be applicable:

  "Well ... now ... if the therapy is oral, then I do not believe there would be any problem. Increase the dose or decrease the dose, for example for higher or lower blood pressure. But for venous therapy, then it is a problem." (Interview 7. Nurse)

The prescription of therapies, or changes in patient's therapies may also not be applicable in certain cases. For example, a participant explored in detail the following case:

"For you to prescribe a medication for the heart rate, it is better to see the type of impulse that the patient has. An ECG, this [SBNHealth] could not record the ECG. I do not believe it would affect the prescription of therapies. You can write a medication for blood pressure, but ... you may not know what else does the patient uses, you may not know what type of life is he/she doing; therefore, I do not believe that we could prescribe therapies based on the values of the vital signs we get from this system [SBNHealth]. It is good to see the patient physically, and not only the values as a number since ... as I said before the heart rate can be good [in the numerical format] but you may notice the blocks in the ECG when being monitored here [in the ECG graph, visualization of data], has a sinusoidal rhythm, has a high number of heartbeats, maybe 100 beats, but for someone this is normal, it represents the rhythm as it should be normally, as maybe the patient has done sports, or has it as a family history. So, I believe that for the prescription of the therapies it may not be very accurate." (Interview 2. Nurse)

Hence, this presents a valid opinion considering the functionalities, values, or parameters that SBNHealth offered. In this regard, to some specific patients that the HCPs know their pathology, anamnesis, and have a detailed overview of their condition, they may contact the patient about therapy changes too, but this may not apply to all chronically ill patients. Nevertheless, a report as a history of measurements for a specific patient when he/she goes for a visit to the clinic was considered helpful for HCPs.

7.5.5.4 Hospital visits and hospitalization days

The findings of this evaluation phase, on the impact of the proposed sensor-based prototype on the number of visits, show that such a remote and continuous monitoring platform may reduce patients' visits to the clinical centres.

> *"Some unnecessary visits to the hospital could be solved remotely. Some complain in certain moments." (Interview 1. Doctor)*

> *"I believe it can even reduce the number, as long as it is monitored from home the patient does not need to come to the clinic. He/she can send the data. "(Interview 7. Nurse)*

> *"It affects and may cause the number of visits to decrease. They will decrease because ... (2s pause) probably patients have had visits every month because I am saying that there are patients who are anxious and psychologically dependent on the doctor. So, they do the measurement from home, they are more comfortable, the doctor tells them [patients] that it is the same measurement, the patient himself/herself sees that he/she is sending the values, that he/she is communicating with the doctor. Instead of visiting every month, it does every 3 months or every 6 months. "(Interview 2. Nurse)*

However, HCPs had different opinions on how the application of SBNHealth may affect the hospitalization days. According to the participants, the application of the SBNHealth may affect the group of patients who are hospitalized just for monitoring for longer periods of time, when for example the doctor suggested to have them under monitoring and have their vital signs recorded:

> *"So ... maybe, a little bit even the hospitalizations can be reduced because it has often happened to us that we have hospitalized the patient, only to monitor him/her during the night. Hence, it can affect the reduction of these types of hospitalizations. "(Interview 2. Nurse)*

> *"I do not know. Maybe, for example, if we think statistically... maybe we would have a week less." (Interview 1. Doctor)*

> *"And for the days of hospitalization, it would probably affect them to get shortened. A patient would probably go home and be monitored from home than stay in the hospital. "(Interview 7. Nurse)*

In this form, based on the participants' feedback, the proposed sensor-based prototype may not have an impact on the number of hospitalization days for the other group of critical patients who need hospitalization and clinical surveillance, for example:

> *"Hospitalizations... I would not say, because a patient who needs hospitalization, he/she will be hospitalized. We monitor the condition but cannot treat him/her at home. "(Interview 3. Nurse)*

> *"No, I do think it [SBNHealth] would have an impact on the hospitalization days. "(Interview 8. Nurse)*

> *"I cannot say that it will affect hospitalizations. "(Interview 5. Doctor)*

As mentioned earlier, the reduced number of visits and possibly the hospitalization days (for some specific patients) has a direct impact on overall costs related to treating and managing chronic diseases. Hence, details on these costs are elaborated in the next subsection.

7.5.5.5 Costs related to chronic diseases

After using the proposed sensor-based prototype and seeing the functionalities that it offered to HCPs and chronically ill patients through the mobile platform, all participants confirmed that the application of the SBNHealth will have an impact on the costs related to chronic diseases, and it will provide overall and in the long term, reduction of costs related to treating and managing chronic diseases.

> *"Hmm ... I believe yes, I believe ... maybe not to such a great deal. However, I believe so. "(Interview 1. Doctor)*

> *".. it would reduce in a way, unnecessary consultations. If a patient suffers chronically from hypertension, it means that this patient is using therapy for hypertension, for a week the blood pressure values are increased, he/she communicates with the doctor about the therapy he/she has used and can make the prescription change through the system and there is no need to go to the clinic. In this way, the number of visits is decreased, the patient costs are reduced, there is no need to pay for the visit." (Interview 3. Nurse)*

> *"Maybe it would reduce them." (Interview 8. Nurse)*

Some participants described in monetary values how the proposed sensor-based prototype may affect a patient's budget considering actual costs that they face for simple medical services, such as measuring vital signs or routine consultations with their healthcare professionals, as explained:

> *"Yes. Costs, yes. Because why should the patient make a visit that costs maybe €5, I am saying the minimum, because in UCCK it is probably free. However, I think it would reduce costs. I have also seen in many cities, in different pharmacies, measuring blood pressure €0.50 or measuring blood sugar €0.50. So why should the patient spend even that €0.50, get a smartphone today that can read vital values, and always measure the values? It is a cost reduction. In the beginning, there are costs, but in the longer term, they will spend less. For example, for patients who have high blood pressure and they need to measure it continuously." (Interview 2. Nurse)*

> *"For example, the blood pressure… that means we put Holters that measure blood pressure and the patient pays €50, and I have 1 minute of work. But with this system [SBNHealth] he/she [the patient] does not have to pay you €50 per day." (Interview 4. Doctor)*

These examples show participants' experiences with chronically ill patients that they monitor continuously in their private clinic and they have to pay various amounts for clinical visits, the doctor's consultation, or remote wired-based monitoring through devices such as Holter that may cost them €50 per day. As the participants mentioned earlier, they put Holter monitors to record the patient's heart rate (one type of Holter), and blood pressure (another type of Holter) for between 24 and 72 hours. Hence, calculating €50 per day, a patient may pay around €150 for single remote monitoring.

Besides the clinical costs, the application of the proposed sensor-based prototype may reduce a patient's travelling costs, travelling time, unnecessary phone calls, and expenses related to them, as described:

> *"Affects in reducing the number of visits. It [SBHealth] affects .. patient costs. On patient travels. Affects the time of the patient, but also the time of the doctor. Now when a patient comes for a visit, the doctor has also to spend around 30 minutes with him/her." (Interview 5. Doctor)*

> *"From the patient side it would have eased the cost of treatment in terms of travels that can be avoided, the use of the phone can be avoided as a cost, these costs can be avoided I think .. so these are some costs that can be shortened from the patient side. Or if he/she is going to come with someone, he/she will have to get a work permit, fuel costs, normally these are significantly reduced." (Interview 6. Doctor)*

These findings show HCPs' feedback on the positive impact of using the proposed prototype for reducing costs related to chronic diseases for patients. This has also an impact on the patient's life, as elaborated in the following subsection.

7.5.5.6 Patient's life

Participants of this interview study had the chance to see also the mobile platform of the SBNHealth prototype that is supposed to be used by the patient. The Android application enables chronically ill patients (among other functionalities) to perform new measurements of their vital signs, see a summary of the last measurement, generate and export reports of vital signs, and communicate the measured vital signs with their monitoring doctors. Considering these possibilities, the HCPs were asked how the application of the proposed sensor-based prototype may affect a chronically ill patient's life.

The findings on the impact of the SBNHealth show some positive aspects of a chronically ill patient's life. Healthcare professionals thought that a patient may feel happier, more comfortable, informed about his/her medical condition, and safer knowing that medical staff is monitoring him/her using the proposed platform, for example:

> *"Also, the patient would go home happier when he/she knows that the doctor is monitoring his/her vital signs." (Interview 7. Nurse)*

> *"(3s) perhaps the patient feels more confident and satisfied. If he/she sees that the doctor is answering him/her, he/she feels a kind of security and says - the doctor is watching me, all the time and I am safe – [patient's words]. For this, I think the patient would be more satisfied with such monitoring." (Interview 2. Nurse)*

> *"I believe it would have a positive effect, as the patient would feel safer. If he/she had any signs [unusual condition] and would be able to express this to the medical staff, I believe he/she would be calmer psychologically as well. It would not be with that stress that -I have something but I do not know exactly, I do not know what I have- [patient's words]. " (Interview 3. Nurse)*

“Yes, certainly very useful. I said that the most challenging thing is to keep notes, notebooks, and on the other hand when he/she has the application that records his/her measurements, so I think it is useful since he/she has a history, the data.” (Interview 6. Doctor)

Nevertheless, participants were asked also about their opinions on how the access of patients to their values of vital signs through the mobile platform would affect their medical condition. In this regard, there were different opinions among HCPs. Some of them confirmed that when the values of the vital signs are not within the normal range, this may affect a patient’s medical condition, for example:

“Yes, if the patients get worried because of the higher values of blood pressure, of course, that this would also affect their health because they get stressed. Stress affects everything. It affects the increase of blood pressure, it affects the increase of blood sugar and even though we have it under monitoring, again the patient is stressed and it can happen that even the therapy does not work. But sometimes also the therapy has both good and bad sides, so does this platform, it has good and bad sides, but ... for this reason, there should be visits to communicate orally with the patient.” (Interview 2. Nurse)

“To some patients, this may probably become psychological - why before I had the value 120, and later it became 130 – [patient’s words]. Perhaps in this part, from the emotional side, there can be changes in vital signs values, if the patient is constantly looking at them. He/she does not know that there are limits that if the values change for one or two degrees, there is no harm. But patients are of different social classes, with different levels of education.” (Interview 3. Nurse)

However, this may depend on the patient’s background and level of education, their experience of reading the values of their vital signs, or knowledge about his/her disease, as explained:

“It depends on the education or the experience of the patient. Sometimes the patient is taught by the experience of reading these values of the vital signs. It may be that he/she has read it somewhere, or someone has told him/her that a heartbeat, or an oxygen saturation, is a fixed value; in this case, the patient wants to see that value and it may happen that for his/her case even a slightly higher value is fine. He/she does not have this information that these changes could be good for him/her. For this reason, the platform can cause concerns, i.e., only in these cases. If he/she is a patient who has read and knows more, he/she knows that even though he/she has higher blood pressure, he/she knows that this value is fine.” (Interview 2. Nurse)

As suggested also by this nurse (in the above comment), this may not apply to patients who have information about their disease, about the normal range of their vital signs, and their pathological condition. According to the HCPs, these patients and their access to vital signs may facilitate their remote monitoring work, as explained:

“He/she [the patient] also feels better when he/she knows his/her condition. Now, for example, in Covid's time, all homes bought a pulse oximeter that earlier even hospitals did not have enough pulse oximeters.” (Interview 5. Doctor)

“A patient knows his/her condition, and simply ... requests monitoring if he/she sees that his/her blood pressure has increased and he/she knows the limits, then it would be positive for us. It would help us in some way.” (Interview 3. Nurse)

Further to this, participants explained that the usage of remote and continuous monitoring through the proposed SBNHealth prototype may be incorporated as part of a patient’s daily routine and, in this way, he/she would get used to it. These participants compared the monitoring of blood glucose levels with the monitoring of other vital parameters, such as blood pressure, respiratory rate, heart rate, and oxygen saturation that the SBNHealth offers:

“The patient might feel stressed at the beginning, but later he/she would incorporate it [SBNHealth] into their daily routine, as part of their life, and take this monitoring very normally, and be aware of it. Similar for example as measuring glycemia. That process too becomes part of life, to measure blood sugar in the morning and evening.” (Interview 7. Nurse)

“I think it would affect in a better context. For example, a patient with diabetes should always have to monitor blood sugar levels also at home. Regardless of whether he/she has a low or high value, he/she should monitor it as he/she should take insulin and it depends on the blood sugar values that the patient has. Thus, the vital parameters are signs that the patient must constantly monitor, after being discharged from the hospital and while being at home.” (Interview 8. Nurse)

Generally, the findings show that the impact of the SBNHealth on a chronically ill patient’s life besides the positive aspects may also cause stress or increase the values of vital signs to a group of patients who do not have enough information on their diseases and their medical condition. However, as suggested, this may depend on the patient’s experience in reading the values of vital signs, their level of education, and their overall knowledge about his/her chronic condition.

7.5.5.7 Healthcare sector of a developing country, Kosovo

This study found that the application of the proposed SBNHealth prototype may also have a positive impact on the healthcare sector of a developing country such as Kosovo. Participants thought that the application of the proposed remote and continuous monitoring prototype may increase the effectiveness of care, reduce unnecessary clinical visits (especially in pandemic situations considering people’s infections), and could change the institutional approach positively if the institutions were willing to use them.

“It would affect positively (convinced) the healthcare sector in Kosovo. I do not know how much the institutions will be ready now, it depends on the will of the institutions, but individually I think that many doctors would have a positive opinion, I believe.” (Interview 6. Doctor)

“This would also affect the health in Kosovo to bring it in a better condition.” (Interview 5. Doctor)

“Perhaps it would increase the effectiveness of care, change the institutional approach, in a positive way, I believe.” (Interview 1. Doctor)

To elaborate further on the impact of the proposed SBNHealth in the healthcare setting, these participants took two examples of how they could implement and use the proposed platform, as follows:

> *"A scenario, for example, we would get the vital signs of a patient who left the hospital three days ago, a patient also in serious condition, decompensated in the cardiac sense. For this patient, I could ask to monitor the rhythm, after we changed the therapy, so I have the vital parameters and there I can see the rhythm, the pulse, for example, if I get 176, I can understand what may have caused it and I can tell the patient to come as soon as possible because you need to be here. That would be enough if the patient arrives on time and we start with other measures, and put in control the rhythm disorder that we just mentioned." (Interview 1. Doctor)*

> *"In my opinion, this system [SBNHealth] would affect the health system in two segments. Under 1, patients will be under monitoring, which is very important. For example, we discharge a patient from the hospital who is from Prizren[8], now he/she has to call the doctor on the phone to ask about a check-up or consult him about something. The doctor may not have time to respond to the patient whenever he/she needs it. So, if this system [SBNHealth] is applied, the patient does not need to come from Prizren here, nor does he/she need to call the doctor, but he/she sends the data and the doctor sees for 1 minute and evaluates the patient's condition. Then the doctor finds a way of communication, for example, if the patient is in a bad condition, he tells the patient to come to visit, if the values are ok, there is no need to come." (Interview 5. Doctor)*

These examples show the readiness of the HCPs to apply a remote and continuous monitoring platform such as the proposed SBNHealth prototype and how it may affect a developing country's healthcare sector, facilitate HCPs' work and improve patient care.

7.5.5.8 Summary

The findings of this evaluation study revealed that the proposed sensor-based prototype has an impact on various aspects of the HCPs' work, the patient's life, and the healthcare institutions in a developing country, Kosovo. From the HCP's perspective, this study investigated the impact of the SBNHealth prototype on the working schedule and workload. According to the participants' feedback, the proposed prototype seemed not to take a lot of time to view a patient's vital signs and communicate with those that are in critical condition through email or phone, functionalities that the platform offered. Furthermore, participants proposed that there may be corresponding medical staff inside the hospital, who will specifically monitor patients at a distance. According to them, this could be arranged between the existing HCPs, internally, so that there may be a group of personnel working with shifts to offer 24-hour monitoring through the SBNHealth to the patients registered there. Participants also proposed that they could set a separate time slot within their working schedule for distance-based patients, considering that they evaluated the usage of the SBNHealth not to take a lot of time and not to affect their workload. Hence, having the majority of participants confirming that the proposed

[8] A city in the south part of Kosovo, 86km from Prishtina (the capital city of Kosovo and where the American hospital was located)

SBNHealth did not seem to overload them considering the regular obligations that they have, presents a promising result for positive evaluation and maybe a successful implementation of the proposed sensor-based platform.

The proposed SBHealth prototype may have an impact on the prescription of therapies for chronically ill patients that are at a distance, considering that patients now have a history of measurements of vital signs. However, this may not apply to patients that are using venous therapy or those in a critical condition and with fluctuating values of vital signs. In this regard, for some specific patients that the HCPs know their pathology, anamnesis, and have a detailed overview of their condition, they may contact the patient about therapy changes too, but this may not apply to all of them.

Healthcare professionals agreed that the proposed prototype may lower the number of patient visits to healthcare institutions. However, this was not the case for hospitalization days. According to the participants, the proposed prototype would only affect those patients who are sometimes hospitalized just for monitoring their vital signs, but for the other group of critical patients that need hospitalization and clinical surveillance, this may not be appropriate.

All participants confirmed that the application of the SBNHealth would have an impact on the costs related to chronic diseases, and it will provide overall, and in the long term, reduction of costs related to treating and managing them. The cost reduction will be a result of unnecessary consultations or clinical visits (just to measure blood pressure, or confirm the therapy), reducing travel expenses, the number of unnecessary phone calls, and the expenses related to them.

Besides the cost reduction, the findings on the impact of the proposed prototype showed that it might make a patient feel happier, more comfortable, more informed about his/her medical condition, and safer knowing that medical staff are monitoring him/her. Nevertheless, the application of SBNHealth from the patient and their access to the values of vital signs for example, when the values are not within the normal range, may affect the patient's medical condition as they may get stressed or worried. However, as confirmed by participants, this may depend on the patient's level of education, their experience in reading values of vital signs, or their knowledge about his/her disease.

Overall, the HCPs confirmed that the application of the proposed SBNHealth prototype may increase the effectiveness of care, reduce unnecessary clinical visits, especially in pandemic situations considering people's infections, and change the institutional approach positively if they are willing to use them.

7.5.6 Challenges for successful implementation

Participants of this evaluation study discussed in detail the challenges that they perceived to have and were related to the successful and practical implementation of the proposed SBNHealth prototype, as follows:

- challenges related to patient and doctor cooperation for remote monitoring through SBNHealth,

  Participants confirmed that there would be challenges on both sides, from both the patient and the monitoring medical personnel. According to the participant's opinions, both of them need to understand how to manage, communicate and transfer gathered data from one to the other, hence have a form of co-operation.

“The challenge would probably be on the other side, on the patient, the co-operation.” (Interview 1. Doctor)

“As a challenge ... for both doctors and patients, I think there are [challenges]. They need to know how to manage, communicate, transfer this data from one to another. This I think will be a challenge when this system will start to be used.” (Interview 7. Nurse)

- challenges from the managerial side to accept the application of the SBNHealth,

  For a successful implementation of the proposed SBNHealth into the healthcare institutions, either private or public, it would require to have permission from the managerial side. Hence, in this context, participants had some doubts and emphasized that the successful implementation of the SBNHealth into medical centres, would be highly dependent on their management. In principle, new and innovative things may encounter some resistance, according to them, for example:

“It's a bit problematic. In principle, new, innovative things have resistance.” (Interview 5. Doctor)

“Because, perhaps, it is also the aspect that the management does not want someone else to bring new ideas to an institution that is private and is known for innovation. Because if it seems good to me, but the management does not want to apply this, then automatically I cannot use it. So, the only challenge I think would be the acceptance by the management and the institution. This is the same for both private and public institutions.” (Interview 2. Nurse)

“I do not know ... maybe the agreement with the private institution is somewhat easier, with the public institution it is a bit more difficult as it is even bigger as an institution and those steps, the stages, are more complicated. In this respect, it can be a challenge.” (Interview 6. Doctor)

- challenges related to payment of medical staff who monitor patients at a distance using SBNHealth,

  Another challenge that is closely related to the managerial aspect of implementing the proposed remote and continuous monitoring platform through the SBNHealth prototype, is related to the payment of the medical staff that will monitor chronically ill patients. This was discussed from two different perspectives, the one that involves payment of the remote monitoring medical staff and the other perspective that affects the incomes of the medical institution, especially for the private ones.

“The problem is all managerial, who pays for this doctor who monitors remotely and tries to incorporate these values into therapy. There is also... for example, the management of this hospital [American Hospital in Kosovo] is interested to have the patient physically here, to bring money. To pay for a visit, an image, some tests. It is the existence of this hospital.” (Interview 4. Doctor)

- challenges related to responsible medical staff for monitoring patients from the hospital using SBNHealth,

  The responsible medical staff inside the hospital that will monitor remote patients was considered as another challenge that should be addressed. As a nurse described, it is important to have a specialist of the field to provide feedback for example to a cardiac patient, as suggested:

  "The only problem is that ... we have limited staff to monitor patients, with three doctors to manage the care for the whole clinic is very problematic. Now I do not know how much the doctor would be able to follow the patients at a distance. So, the possibility is low. To monitor patients remotely, it would be necessary to have a specialist, for example, a cardiologist and not a general practitioner." (Interview 7. Nurse)

  In this regard, participants even suggested that the remote monitoring of patients can be done to other ambulatory clinics, in order not to overload the tertiary medical service, for example:

  "A family doctor can deal with the treatment of patients at a distance or maybe a small private clinic. Usually, university clinics do not deal with remote monitoring of patients, because there is performed the treatment of patients in serious condition, however, when they [patients] are discharged from the hospital they continue to the rest of the second-hand care clinics, for further monitoring." (Interview 4. Doctor)

  "Because mostly, this [the SBNHealth] I believe would be suitable for ambulances, as it presents patients who have slight symptoms." (Interview 3. Nurse)

As presented above, healthcare professionals discussed possible challenges in various aspects of clinical usage of the SBNHealth prototype. Hence, starting from a top-down approach:

a. there should be a managerial will from the healthcare institutions to use and provide a remote monitoring platform to their chronically ill patients,
b. management of healthcare institutions should arrange the monitoring personnel also inside the clinic, and their financial aspects of providing distance-based monitoring, and last but not the least,
c. doctors and remotely monitored chronically ill patients should arrange a communication channel, or a flow, to understand each other and work together for better monitoring.

As well as these proposals, the healthcare professionals had some very interesting suggestions on how to further improve the functionalities that SBNHealth offered to them. These details are discussed in the following subsection.

7.5.7 Suggestions for further improvements

The HCPs proposed additional functionalities that could be incorporated into the proposed SBNHealth prototype to further enhance the user experience, provide better patient monitoring, enable safer doctor-patient communication, and support a wider range of patient profiles.

Considering the tasks that participants performed with the proposed sensor-based prototype they had some suggestions to add other information such as gender, taking into account that some conditions as more common to females, others to males, hence it was considered important to have the gender displayed as part of the patient's information; or vital signs such as temperature, blood sugar or even visualization of the heart rate through the ECG.

> *"I would just suggest to you in terms of vital parameters if there is the possibility to have the temperature as well." (Interview 1. Doctor)*

> *"The frequency [heart rate] shown as a number it may look good at a normal value, but the shape, or graph, may not be accurate, real… the ECG." (Interview 2. Nurse)*

> *"Age, weight, maybe it would be good to have a patient's gender as well. Because the gender ... gender is a characteristic in medicine that should be included. Since some diseases appear more in women, the others more in men." (Interview 1. Doctor)*

> *"Maybe in the vital signs, in addition to blood pressure, heart rate, it would be good to include blood sugar too, diabetes." (Interview 2. Nurse)*

> *"Maybe we can also add blood sugar, enter it as a value, for example, the patient can measure blood sugar at home and then save the value through the app. So, if there is room for additional parameters." (Interview 6. Doctor)*

Another interesting idea from a participant was to add non-metric data. In this case, the patient to add himself/herself a value of a vital parameter, and possibly other details regarding that condition, for example:

> *"But the same platform can serve you as an idea for the patient to enter the data into the phone. For example, on January 29, a headache, at 09 o'clock begins, at 19 o'clock ends, the intensity: Strong, Light, Medium [dropdown list that the patient can choose an option], analgesics: I took / I did not take, and something else for a note [the patient to write a note]. This would be information for us that when the patient comes after one month, we were close to the patient's profile and we may see for example five pains per month, compared to the previous month, and analyse the data for example if there were less or more issues. Maybe the application can be enriched with non-metric data." (Interview 6. Doctor)*

Similarly, participants suggested that it would be good to have a communication channel with the patient and everything saved as a record. Hence, the healthcare professionals to have a history of communication with the patient, for example, anamnesis, their main concerns, symptoms, therapy changes, test results, or other communications between the doctor and the patient, as explained:

“Anamnesis and symptoms also would be very welcomed. Now if the patient could write something, main complaints, what symptoms is he/she having, headache, chest pain, so that we can map them with the values of the vital parameters. Hence, even in cases where we suggest something to the patient, add a medication to his/her therapy according to the parameters we get from the sensor-based platform, the recommendations that we have provided in that case to the patient; it would be good to have a record for such a case so that we can go back later on.” (Interview 1. Doctor)

“When the patient wants to communicate with the doctor it would be good to have a possibility for the patient to write here [in the SBNHealth portal] and for us [medical staff] then to provide an answer and not to make the request through the email.” (Interview 3. Nurse)

“Another suggestion I now remembered, the patient's condition. So, if it is possible to include that also in this system. For example, the patient may have good test results, normal values of the vital signs, but may not feel well. Furthermore, if the patient has done the tests in Prizren, then it would be good to have a possibility for him/her to enter [upload] those results in the system so that the medical staff can see them in Prishtina.” (Interview 5. Doctor)

For chronically ill patients who are in a critical condition, healthcare professionals suggested having a form of notification sent to them, to alarm or attract their attention for an emergent intervention. For example, when a patient’s heart rate increased and was not within the normal range or similar cases as explained below:

“For example, we had a patient in a good condition until yesterday, today we have measurements that are out of the normal range, we are notified and the patient is somehow marked with a red flag [mean in the table of critical patients in the web-portal].” (Interview 1. Doctor)

“.. to have an alarm or a special sign when there is a parameter out of the normal range, those minimum and maximum values, if there was something out of those values, so we can respond immediately.” (Interview 2. Nurse)

For healthcare professionals, it was very important that the values of the vital signs that they receive be from their patients. In this context, a nurse even recommended adding fingerprint recognition for every patient account, just to be sure that every measurement belonged to the specific patient and not, for example, to a family member or someone else that is using the patient’s device or patient’s account, for example:

“Maybe it would be better to recognize the fingerprint as well. To have only one fingerprint, one account for one finger. That finger should belong to the patient only. When the patient opens the account, maybe he/she can also register the fingerprint, in this case, to avoid others sending their vital signs through the patient’s account. In this case, the doctor from a distance cannot know if the values belong to the patient or someone else.” (Interview 2. Nurse)

Some other suggestions include:

- translate the application into Albanian, or offer other language possibilities,

"This application is in English, it would probably be good to be in Albanian given that patients are elderly people, and probably most of them do not speak English." (Interview 1. Doctor)

"I would add the possibility of language. For example, Albanian, as not everyone knows English, or even any other language Macedonian, or Serbian as it includes more provinces. Because it also affects the use aspect of the platform." (Interview 2. Nurse)

- have a separate sensor-based device, like a watch or wrist device,

"Also be a device, like a watch you recommended, and in this form, I believe it would be very welcomed. I believe that most of the patients I know, that I have in mind, most of them would accept this form of monitoring of their condition and consider it as approximate and effective." (Interview 1. Doctor)

- use the SBNHealth for research purposes,

"We can, for example, perform studies with patients in such cases. For example, patients who had interventions such as hysterectomy, if they are older patients, have higher blood pressure, increased pulse, heart problems. A group of patients is selected and monitored remotely and then a comparison is made between them." (Interview 3. Nurse)

- make phone calls from the patient app,

"Only what I mentioned earlier, that if the patient was monitored for example until 4 pm and his/her condition worsened after 4 pm, he/she tried to contact the doctor to talk about the condition, but the doctor at that moment has not been online, then let there be the possibility to make the call over the phone. So, in addition to the application, there should also be the possibility for the patient when he/she needs to have the opportunity to call the doctor on the phone." (Interview 3. Nurse)

Further to these suggestions, healthcare professionals emphasized that for them it is very important to have accurate values of vital parameters. Hence, in two cases, they noticed that the values of the blood pressure were not showing logical numbers, maybe because the researcher [AB] was speaking during the measuring interval, or moving the hand; however, they suggested that there should be a validation of these values, for example:

"Yes, this is incompatible. As a vital parameter. The diastolic to be higher than systolic, is incompatible. Life incompatible." (Interview 1. Doctor)

"For example, I am looking at the blood pressure, pulse, saturation, but blood pressure are we sure that this value is real? Now I do not know how functional or not, but a blood pressure of 118 with 110, does not seem to be a real value. So, 130 with 80 may be a real value, but it's more a technical matter of how you validate it." (Interview 6. Doctor)

Generally, all the proposed new functionalities and improvements are doable. It is just a matter of how they will be incorporated into the existing prototype and fit with the aim of the overall study. The following subsection will provide more details on the evaluation of the existing functionalities that the platform currently offers to healthcare professionals.

7.5.8 Suitability for the task

This evaluation study aimed to understand whether the SBNHealth prototype included functionalities that enabled healthcare professionals to fulfil a task. The tasks included actions that participants made with the system, for example, accessing a patient's vital signs, adding a patient for monitoring, communicating with the patient remotely, visualizing remote patient information, filtering critical patients, and similar actions.

All participants agreed that the proposed sensor-based prototype contains the functionalities that enabled them as medical personnel to see patient’s vital signs. They were glad that the platform offered also the possibility to add the range of minimum and maximum values for every patient, for example:

> *“Well, more than appropriate. It did not seem to me that something should be added. Even the limits [the range of min and max values for a patient's vital signs] were, when there was something more urgent, the system itself showed that this patient was in a more critical condition and he/she takes priority.” (Interview 3. Nurse)*

> *“It's very convenient. Absolutely. These are 4-5 vital parameters that talk about the patient's condition. Sometimes a pathological parameter, that is not a normal value for one patient, for another patient may be a normal value as it is based on pathology. So, the doctor who deals with the respective patient knows the pathology, then these parameters as basic information, are enough. While all the functions of how the system is presenting values, from numeric values to tabular and graphical values, are perfect.” (Interview 5. Doctor)*

Further to this, graphs and tables that were used to present patients' vital signs were evaluated as two of the most used and usual methods to show a patient's vital parameters. They were considered as suitable, appropriate, and simple to use:

> *“Very suitable, appropriate. More than appropriate. Very simple, very good.” (Interview 1. Doctor)*

> *“No, they are very convenient. More than understandable.” (Interview 3. Nurse)*

For a graphical representation of the values of vital signs, participants confirmed that sometimes for them it is easier to read and see the changes using this type of data presentation, as explained:

> *“The table is good; the graph is good too. It may be easier for someone to read the table. Sometimes ... the graph is better because sometimes you do not even have time to analyse the numerical values, maybe the eyes get tired, you are very tired, and having the values as a graph for the medical personnel is easier to notice the wave of values when it is too high and immediately alarms that something is not good with the patient. You also have the functionality to see the details and then you understand more specifically every information. So, the table can sometimes be tiring, as you need to read the values one by*

one, while you look at them [vital signs] faster in the graph. Both [the table and graph] are acceptable." (Interview 2. Nurse)

Besides the functionalities to view patient's vital signs, the proposed SBNHealth prototype had also the functionalities to communicate with the patient through phone or email. Furthermore, the medical staff could send a notification to a remotely monitored patient. These functionalities seemed very appropriate for communicating with a distance-based patient either through phone, for emergent cases, or through email when the medical staff wanted a written report:

"Personally, the easiest way to communicate with the patient is by email or in writing. The phone is annoying to me, to constantly ringing… because on the phone it takes time to understand who is calling, you have to find that patient's file and at that moment I may not have it, and it is annoying to me because in the middle of work the phone rings and sometimes I may not answer. Then there is the complaint that you do not answer. So, it's a lot easier when the patient has notes, sends them during the day, and I can set aside half an hour at the end of the schedule, log into the platform [SBNHealth], enter the patient code, look at the history and can respond to the patient through the email, hence in writing." (Interview 6. Doctor)

"As two methods used everywhere in the world. Very functional. The medical staff can choose as they have both available in the system. Email is to make things easier for the patient, for example, the monitoring staff writes a few sentences to the patient about his/her condition, meaning what the doctor thinks about his/her condition. It is also the telephone that if the medical staff needs to respond with any urgency. Another communication method I do not think is necessary for us." (Interview 5. Doctor)

Healthcare professionals confirmed that having a filtered list of patients in critical condition helps them to easily access and contact those in need or emergent cases, for example:

"Yes, it is also very good, since ... maybe if the patients were numbered, for example alphabetically listed, a patient who is more critical ... maybe at the moment you do not recall that critical patient or another patient that was in good condition but later on his/her situation has worsened ... now for the medical staff, to find the person, search for that patient, it takes time; so, these patients should appear first, i.e., the patients who are most critical." (Interview 2. Nurse)

"Very helpful, very good. When you as medical staff have a list of critical patients, it means the system tells you that out of 10 patients, or 20 patients, today two are more critical, then it is easier for the monitoring staff." (Interview 5. Doctor)

"Well, very good. This is a very good idea. It means distinguishing patients in critical condition from those in more normal condition. Very well thought, great functionality." (Interview 7. Nurse)

Regarding the functionality to add a patient that the medical staff want to monitor remotely, participants confirmed that it was an easy process to enter a patient's unique code and also the interval of minimum and maximum values for every vital sign. This functionality was considered to allow medical staff to monitor a higher number of patients easily, as also explained by the participants:

"Yes, that is good too, why not. You may not be able to physically visit many patients, but here in the system you can see even 100. It is fine. It does not take you a lot of time." (Interview 2. Nurse)

"We added the patient through the code. It was easy, simple. You just have to open the email once and then enter the code. This is a bit complicated as you should always have the email open. But we constantly use it, I do not think it is a problem for the staff." (Interview 3. Nurse)

"I did not have any difficulties. It was good. With one click you can add a code that comes to your email. It's very easy. It was very good." (Interview 7. Nurse)

Within the proposed SBNHealth system, healthcare professionals also can change the measuring interval of a patient's vital signs depending on the patient's condition. For example, the monitoring personnel could ask the patient to send values of the vital signs every two hours. In this case, the patient was receiving a notification about this change, and he/she could approve or decline it. In case the patient wanted to send the values of the vital signs every two hours, then the monitoring personnel were informed through an email and could see the patient's data every two hours updated in the SBNHealth prototype. This functionality was confirmed to help in monitoring the patient better, as, according to the participants, the patient may not understand and know when a slight increase in any of his/her vital parameters may be a precondition for other complications. Hence, the monitoring staff may notice such a case, based on the patient's pathology and condition, and ask to change the measuring interval.

"This was also very good because ... for example, the patient does not know if he/she is in a stable health condition or not. We have given these values [the measurements of the SBNHealth], but ... for example, we sometimes even know the predispositions of what the patient has. For example, if we see that his/her blood pressure is increasing, and maybe every two hours it is increasing by two degrees. It does not seem alarming to the patient, but for us, it is. We know that this patient has a predisposition to have increased blood pressure and we choose to monitor him/her all the time. On the other hand, the patient receives a notification and realizes that the doctor wants to monitor him/her and approves it." (Interview 2. Nurse)

"Very good. Very good, because now you do not need to burden either the doctor or the patient with data all the time, for example sometimes it is enough to monitor every two hours for a certain patient or even the possibility for the patient to send the data when he/she does not feel good." (Interview 5. Doctor)

Some participants further confirmed that they liked this functionality in the SBNHealth prototype, as it was very similar to the working methods that they apply also inside the clinic when the patient is hospitalized, for example:

"It was very good. The same way we work also in the department here [in the clinic]. Normally not all patients require the same care. Some patients have chronic problems for example with blood pressure, and if he/she continues to have hypertension then more frequent measurements are normally required. Under normal circumstances, vital signs

are measured every two hours, except when the patient has a problem, more specifically. Meaning this feature was fine." (Interview 3. Nurse)

"Right now, even within the clinic, these measurements are done in this way. To some patients, we do measurement more often, to other [patients] all the time. So, I think it is a good idea to have similar functions also in this system [SBNHealth], as it fits us with the practice we have here in the clinic." (Interview 7. Nurse)

In this context, the monitoring staff also could ask the patient to transmit vital signs in real-time. According to participants, this may be a feature that they would apply only to a specific group of patients, as receiving real-time data would be more time consuming for them to monitor and evaluate all of this information, as they explained:

"This was a very good possibility. But in real-time, the problem is probably how much the doctor will be willing to accept data in real-time. Perhaps it would be good for the system to alert for example that a patient has a problem that we need to monitor in real-time." (Interview 5. Doctor)

"Even this ... even this, is good. If the blood pressure at the moment you wake up is high, it is understandable that it is not good. Or the patient, for example, before going to sleep ... his/her heart rate is decreasing ... On the other hand, the medical staff sees that at 3 am, at night the patient has a high heart rate value, then this gives us an indication. So, for the medical staff, the time is important." (Interview 2. Nurse)

"I do not know ... the patient I believe would feel safer, more supported, monitored. He/she [the patient] would feel better. For the staff... I would say ... good luck (laughs) hope they will not get tired." (Interview 7. Nurse)

Furthermore, a participant even declared that, when at home, the patient does not need to transmit data all the time; in case he/she needs to do this, then the patient should be hospitalized:

"We use this method, all the time when the patient is in the institution and we monitor him/her all the time. Now when the patient is at home does not mean to be monitored all the time because he/she is not in the hospital." (Interview 1. Doctor)

These comments provide important feedback on users' perceptions and experiences with the functionalities that the proposed SBNHealth prototype offers to them.

7.5.9 Self-descriptiveness

Considering the positive evaluation of the functions of the proposed sensor-based prototype, on the usefulness and suitability for the task, in this subsection, the results on the self-descriptiveness of the SBNHealth are presented. Self-descriptiveness means that the system offers functionalities that are easily understandable by the users. In this context, the participants of this evaluation study, also considered as users of the proposed SBNHealth platform, confirmed that the functionalities were easy to understand, and the terminology was related to the task, as confirmed:

"Yes, it seemed easy to me. Very easy, very accessible, effective." (Interview 1. Doctor)

"No, the system was very understandable." (Interview 2. Nurse)

"Yes, yes. It was fine, for example, the confirm button, it saved the data so it confirmed the status. Or the possibility of adding a patient, it added the patient." (Interview 3. Nurse)

"Yes, I understood. Overall, yes. Maybe in detail 100% no, but I can say an 85-90% I understood them. The system seemed very clear to me." (Interview 8. Nurse)

"But this platform [SBNHealth] seemed very easy to use, especially for young doctors who have experience with digital technology, this is very useful." (Interview 6. Doctor)

Nevertheless, the SBNHealth seemed easy also to one of the participants, who was more than 65 years old, hence, considering the above comment, the age of the doctor may not be considered as a problem to use the proposed prototype, for example:

"Easy (convincing). It seemed very easy to me. Nothing complicated." (Interview 5. Doctor)

Icons were used to make the system more self-descriptive. In this regard, participants liked the utilization of icons for visualizing the functionalities of the system, for example, the add button icon, or the real-time monitoring icon; and they considered them as appropriate and understandable, for example:

"Yes, they are fine." (Interview 2. Nurse)

"Yes, a lot. Very practical. Very good." (Interview 4. Doctor)

"They are appropriate and understandable." (Interview 8. Nurse)

Further to this, healthcare professionals declared that the arrangement of links and information followed a logical order, and they were presented in a simple way and not crowded or overloaded:

"Well, it was logical." (Interview 5. Doctor)

"Yes, yes. They were very good. Simple, sorted logically." (Interview 7. Nurse)

"No, they are shown in a logical flow. Not overloaded." (Interview 8. Nurse)

Healthcare professionals seemed to like and understand the functionalities of the platform and the visualization of the information, as they confirmed also in the comments below, they had no suggestions on how to further make the system more self-descriptive:

"No, it was not good. The colour is also good. The information that was important was highlighted. Which means they get your attention." (Interview 2. Nurse)

"I do not know. I have no idea. There was not much data or information in the system. I did not find something that was too expressive that may cause a medical staff to get lost while using the system. I thus created an impression of this system and I do not think there is something that needs to be changed." (Interview 5. Doctor)

According to the healthcare professionals' feedback and their comments, they all seemed to have a basic understanding of the functionalities of the SBNHealth prototype. From their experience with the system, it seems that they considered it to be easy to understand and sufficiently self-descriptive.

7.5.10 Controllability

This evaluation study also investigated the controllability aspect of the proposed SBNHealth prototype. This included an understanding of healthcare professionals' feedback whether they perceived to have control over their actions performed with the system. This included system information and possible security leaks for accessing patient information.

Healthcare professionals confirmed that they had information on the actions they were performing with the system, hence they perceived the system was informing them about the progress of the user's actions, for example:

> *"They were... fine ... because when you select the refresh button and it immediately shows in colour the change made. It was good. Everything was as it should be and simple. Not something complicated that you clicked and it [SBNHealth] did not save the value, or something complicated that you clicked and had no idea what you clicked." (Interview 2. Nurse)*

> *"Yes, yes, there were enough informative messages. We saw the notification when we changed the way the data was transmitted. Then we received the email and on the web portal the button became red." (Interview 3. Nurse)*

Participants were receiving an email notification with the patient's unique code, once the patient was authorizing the medical staff to receive his/her vital signs. Hence, the monitoring staff could enter the patient's unique code into the SBNHealth platform and see this patient's vital parameters. According to participants of this evaluation study, this restriction that only authorized healthcare professionals could access patient's information was appropriate and it is the patient who should decide with whom he/she wants to share the data, for example:

> *"That is the best thing. It is the best thing. For me, it is the best thing because I think you have evaluated it very well, that my data, for example as a patient, should not be seen by all staff, i.e., anyone who has access to the system. These are very important things, it is also the ethical side, the rights of the patient, that he/she has to decide in this aspect with whom he/she wants to share this information. It may happen that you do not even want to share them with your family, nor with all the medical staff. "(Interview 5. Doctor)*

> *"Maybe ... this ... when the patient adds the doctor ... that part is more related to patients ... so that they have their doctor and cannot add other doctors. So, this part is good. The doctor I believe would not misuse patient data. Normally we know these are sensitive information, so it is better to have limited access, authorized access." (Interview 2. Nurse)*

> *"Because there are patients who ask for their privacy to be protected. Since he/she has chosen a doctor, it means that he/she wants to be checked by that doctor and not by any other doctor. So, I believe it is okay, it is better to have it coded [unique patient's code] like this. So, to maintain privacy." (Interview 3. Nurse)*

"Well now .. maybe .. it is not a bad idea for every patient to have their doctor, and every doctor to know the details of his/her patient. Now even the doctor is not even interested in knowing the data of other patients who are not under his monitoring. So, this code [unique patient's code] limits them [medical personnel] in that aspect. For example, as a nurse, I am not interested in what test results have patients in other departments. I care about the patients here [in this department] that I have a responsibility for them. So, it seems to be fine." (Interview 7. Nurse)

In this regard, to further enhance the information security, for example, the patient's vital signs, the healthcare professionals declared that there was no need to provide additional restrictions considering that the SBNHealth platform currently contains only values of the vital parameters, and not the patient's diagnosis, disease information or similar sensitive information, as confirmed below:

"No, I do not believe it is necessary, because vital signs are general parameters that do not make you think that a patient has a problem, or that the privacy of those values should be maintained. If there was a more specific diagnosis then it is better to take some safety precautions. But just for the vital signs, I do not think it is reasonable to impose more security measures." (Interview 7. Nurse)

"At the moment, no. At the moment, no." (Interview 1. Doctor)

"No. I believe the code is enough. I do not believe someone will try to obtain that code and access someone else's data." (Interview 5. Doctor)

The patient, on the other hand, may want to add also other personnel to have access to his/her vital signs, and this may include also family members. In this context, healthcare professionals thought that monitoring physicians, or caregivers, or family doctors, would be appropriate to have access, for example:

"I believe it would be necessary, especially the monitoring physician. As we mentioned before, the doctor is not there all the time and the patient may need him, but the doctor is not there at that moment. So, a person, the attending physician, but also a family member, why not, if the patient selects it." (Interview 3. Nurse)

"Yes, definitely, I think it would be good for the family member or a caregiver to have access as well." (Interview 7. Nurse)

"As long as the patient voluntarily allows the other staff, I believe it is fine. Why not, it will not be a problem." (Interview 1. Doctor)

However, for family members there were some doubts about whether they should be given access to patient's information:

"Caregivers, yes. I think so. While for the others I think there is no need." (Interview 8. Nurse)

"No. I do not think they should have access. Now in this case we may have patients who for a health problem do not feel comfortable sharing it with everyone. On the other hand, it can happen that the family members also use the patient's application, take measurements, and we get those measurements." (Interview 5. Doctor)

Nevertheless, this remains open for discussion as the patient currently on the SBNHealth platform, the mobile application; has no restrictions on his/her side on the authorization part. Hence, he/she may share the vital signs with any person. Therefore, it is the patient responsibility to maintain his/her data privacy and choose with whom to share the values of the vital signs.

7.5.11 Conformity with users' expectations

Another important aspect of new platforms is the conformity with users' expectations. Considering that, during the first interview study (chapter 5), data were collected on healthcare professionals' opinions on a remote and continuous platform that would help them monitor their chronically ill patients at a distance; in this evaluation study the functionalities implemented on the proposed sensor-based prototype were evaluated as to whether they were consistent and complied with their requirements.

The aim of using the SBNHealth prototype is to enable healthcare professionals to monitor their chronically ill patients continuously and remotely. Hence, in this regard, the participants confirmed that the proposed platform contains sufficient information on a patient's vital signs that would help accomplish and facilitate the medical staff's tasks that they need for remote monitoring, for example:

> *"In terms of critical monitoring, these vital parameters are sufficient. These vital parameters provide an idea of what and how. If we talk only with parameters. Because now I do not know, but if we talk with parameters, they are fine." (Interview 1. Doctor)*

> *"Yes, yes it meets our needs. In the aspects we talked about before, it means that the medical staff is calmer, it will not stay thinking about the patient whether he/she is good or not, but he [the doctor] can look through the system. Even the patient is calmer, safer as he/she is under supervision. It is much safer when you have the data for a period of time." (Interview 5. Doctor)*

> *"Yes, it monitors the patient. Most important things are there [vital parameters]." (Interview 2. Nurse)*

The other functionality that SBNHealth had, was the possibility to generate a report of measurements for a period of time. The healthcare professionals confirmed that even now they advised the patients to perform measurements more often and write them down on paper so that in the next clinical visit they could show the values to the medical staff. Nevertheless, using the SBNHealth prototype, the patients could generate a report of measurements automatically, which is considered as another advantage that the proposed platform offers to patients and the monitoring staff, as elaborated here:

> *"As it has happened so far, the doctor advised the patient to write down the values of the vital signs in a letter, and then when he/she came to visit the doctor looked at them. This has also been good, but not everyone would have done it. It is simpler to put your finger on the camera [as it is the mobile application of the SBNHealth] and take the measurement automatically, than for the patient to write down all the measurements himself/herself. Maybe he/she loses the letters or does not remember for 1 month what the values were. With this system, it can measure blood pressure and other values every day and has their records." (Interview 2. Nurse)*

"The cardiologist would be able to... when giving a blood pressure therapy, the first thing he will do is to monitor the blood pressure within a week, or within two weeks, and tell the patient to measure it twice a day and write them down in a notebook. And then, this is useful because the patient no longer has the notebook, which is often problematic for someone to write or keep notes because he/she does not have the practice of noting down things [writing in notebooks], or keeping a note of his/her parameters ... and he/she [the patient] has it very easy, just puts the finger on his/her phone and they are automatically transferred. This is also convenient for the doctor because when he sees it after two weeks when a patient goes for a check-up, he [the doctor] sees them [vital parameters], has the measurements on his computer, and looks at them without any problem." (Interview 6. Doctor)

".. is very useful. It facilitates our work. We also tell patients: 'Measure your blood pressure as often as possible and write it down in a list [doctor's words to their patients]." (Interview 4. Doctor)

"It would be very important ... The good thing about this remote monitoring system is that we as medical staff also have an overview of the patient. When he/she comes to visit after 1 week I have the report for him/her, and the values for every measurement. I have a detailed report with information about his/her condition." (Interview 5. Doctor)

"This would work very well, because many doctors want a history of the values of certain parameters, for example, blood pressure. They [medical staff] want to have an overview of how these parameters were for longer periods of time, for example before the patient's visit, in the past few days, or weeks. For example, when the patient comes for a visit for 30 minutes, then within this time we [medical staff] cannot know the history, we see the values on the spot, but do not know if there are fluctuations or changes. So, when the patient has the measurement report for a week or during 2-3 days, it is much easier for the doctor to see the values." (Interview 7. Nurse)

Besides the functionalities that the SBNHealth offered to its users, there are also another two important aspects that need serious consideration, especially when discussing the application of digital technologies into healthcare, and these are the platforms' reliability and their performance. Regarding the performance, the healthcare professionals evaluated the SBNHealth to perform good and fast:

"Very good, 30 seconds, not slow, good." (Interview 1. Doctor)

"It was fast." (Interview 2. Nurse)

"The system is working very well. It seems so useful." (Interview 7. Nurse)

However, for the reliability of the proposed SBNHealth platform, healthcare professionals discussed it according to two different aspects. The first aspect that needs consideration is related to the sensor-based device that performs the measurements, and the other aspect has to do with the persons who use the device to perform measurements. Hence, according to participants, the SBNHealth platform would be reliable as long as the sensor-based device that performs the measurements is validated technically and provides accurate values of the vital signs, for example:

"I believe, as long as the measurement is accurate because that too is an issue we need to keep in mind. Probably a technical detail of the device that the patient uses. How accurate is that measurement? Can we rely on it? That is the issue." (Interview 6. Doctor)

Another aspect discussed in terms of the reliability of the SBNHealth platform was related to the person who uses the sensor-based device to take measurements. According to the healthcare professionals, the patient may give the sensor-based device to other persons, i.e., family members, and the monitoring personnel may receive other person's values believing that they are from their patient, as explained below:

"It is reliable since the doctor knows more or less the patient's condition and can know his/her situation, the values he/she sends, but there is a risk that a family member will use the application and transfer the data to the patient's account." (Interview 2. Nurse)

"For this .. I do not know now. I mean .. because for example a patient can .. at home we do not know what the patient does, how reliable the patient is. This is the problem. For example, we have registered a 54-year-old patient, while the patient ... because there are different patients, they can give the sensor to an X family member. It means we cannot know how reliable it is. Is it the patient we are monitoring or is it just another family member?" (Interview 3. Nurse)

This is an important aspect that needs careful consideration for ensuring the authorized access, and appropriate data access, to ensure the platform's reliability so that healthcare professionals can use it and rely on the values of the vital signs they receive. This would be very important, as healthcare professionals considered the SBNHealth prototype to increase their job performance and facilitate their work:

"Yes, it will affect ... but I do not believe it will cause difficulties. I believe that the performance of everyone if they try such ... a system [the SBNHealth], I do not believe that it would be negative." (Interview 3. Nurse)

"(3s) for example, to increase it, if ... you have a critical patient and you tell him/her to measure the values at a distance, without having to come during all the time. We can consider this as increased performance. Because in addition to the patients you have under monitoring in the clinic, you are also monitoring a patient who is at home." (Interview 2. Nurse)

"I do not believe it causes difficulty. It eases ... that feeling ... it is better for the patient when it is continuously monitored, but it also saves the doctor's time, and it eases the burden that the doctor has, thinking about how a patient is. Communication may be by phone, or coming for a visit for something small, a measurement for example .. all this is facilitated by this system [SBNHealth]." (Interview 5. Doctor)

"No, I believe it would increase staff performance. I think the doctors would be much more progressive, much more privileged when they work even with patients at a distance and are aware of their condition. A lot better." (Interview 7. Nurse)

"I think it would improve because a new system at work is both a relief to us and a much more convenient way for us. After seeing the functions of this system, it seemed very clear and appropriate." (Interview 8. Nurse)

Consequently, this subsection discussed various aspects related to conformity with user's expectations, starting from the functionalities that the SBNHealth platform offered to healthcare professionals, and continuing to its performance and reliability.

7.5.12 Suitability for learning

Considering that users of a system can have various backgrounds and demographic characteristics, the proposed SBNHealth prototype should always be effortless to learn how to use it. This was confirmed also from the participants of this study who used the proposed sensor-based prototype, for example:

"So, it did not seem difficult to me. For medical personnel, it did not seem difficult. From the staff's point of view, it seemed very accessible to me." (Interview 1. Doctor)

"Yes, it seemed very easy to me." (Interview 7. Nurse)

However, two participants suggested also having the proposed platform in the Albanian language, as the first language of the participants. This possibility would further ease the process of learning and using the proposed SBNHealth prototype:

"Yes, it is ... it is simple only that if it had the option of Albanian language or user language, it would be simpler." (Interview 2. Nurse)

"This application is in English, it would probably be good to be in Albanian given that patients are elderly people, and probably most of them do not speak English." (Interview 1. Doctor)

Participants discussed whether the proposed sensor-based prototype is easy to use by all levels of users, i.e., of various backgrounds, educational levels, and ages. In this regard, a nurse had some doubts regarding the age of healthcare professionals. She explained (as shown below) that medical staff of 45 or 50 years old, may find the SBNHealth difficult to learn:

"Normally older people who are not used to technology will have difficulty with such systems. But I do not believe that young age groups have a problem. Older age groups are excluded, over 45, 50, normally they may find it more difficult, as they are not faced with technology every day, except for the phones that they use or some simpler systems. It can be a problem for them. But for the young age groups, I do not believe they may have a problem." (Interview 3. Nurse)

Nevertheless, this was not the case with the opinions of other participants, considering that one of them was over 65 years old, for example:

"Maybe age makes a difference, a bit, but I do not believe they will have any problems for using it [the SBNHealth." (Interview 7. Nurse)

"Yes. I believe for everyone it will be simple. I believe it would be a relief for everyone." (Interview 8. Nurse)

"For the doctors, I believe everyone can use it. Even different age groups, even different experiences, can apply it, can use it." (Interview 5. Doctor)

To help all levels of users learn the platform easily and use it, this research study also evaluated the need for training, hence whether additional training was needed to use the proposed SBNHealth prototype. Most of the participants confirmed that a short amount of training may be needed and this for elderly doctors or those that may need it, as explained:

"No. Personally speaking, there would be no need. Maybe for patients, for someone older, maybe yes. But I do not believe that there is a need for medical staff because it was simple." (Interview 2. Nurse)

"If this system is implemented in a hospital, staff retraining is normally needed. But I do not believe that it takes much time for training." (Interview 3. Nurse)

"I believe that with a 1 hour or 2-hour training, even I, that consider myself more as a beginner in these technologies, I would understand." (Interview 5. Doctor)

Hence, considering the above findings on the suitability for learning, the SBNHealth prototype was evaluated as simple and easy to learn, but for a group of specific users, i.e., elderly people or people who are not experienced with technology, according to participants, a short amount of training may be needed.

7.6 Discussion

Participants in this evaluation study confirmed that they did not have a similar remote and continuous monitoring experience with sensor-based platforms. However, they had the chance to perform some tasks with the proposed sensor-based prototype (SBNHealth) as part of this research study. Hence, before the interview questions, HCPs registered on the platform added a remote patient for monitoring, added the range of minimum and maximum values for each vital sign (heart rate, oxygen saturation, blood pressure, and respiratory rate) for a patient, viewed the list of critical patients (patients who had a vital parameter outside of the normal limits), contacted the patient through email or phone, viewed the details of the patient, viewed the vital signs in graphical or tabular form, changed the transmission mode of patient's vital signs, sent notifications to remote patients, and viewed patient's vital signs in real-time. These were the functionalities that SBNHealth offered to HCPs. The researcher [AB] performed the role of the patient and used the Android mobile application to record vital signs, generate reports of values within a period of time, and transmit these data to HCPs. This scenario was performed with every participant in this evaluation phase.

The findings showed a positive attitude towards clinical usage of the proposed sensor-based platform and a list of advantages that were discussed by the participants, after using the SBNHealth prototype. They considered the proposed prototype as a useful tool for remote monitoring of chronically ill patients. Furthermore, the five parameters shown in the platform were evaluated as the ones that could help the healthcare professionals and could be useful to them, to monitor their chronically ill patients.

Considering their intention to use and apply the proposed SBNHealth into their clinical settings, the healthcare professionals suggested various additional functionalities to the proposed sensor-based platform, that would further help them to provide better patient monitoring, enable safer doctor-patient communication, and support a wider range of patient profiles. Hence, healthcare professionals suggested also having non-metric information into the SBNHealth, a history of communication with the patient, i.e., anamnesis, main concerns, symptoms, therapy changes, test results, or other communications between the doctor and the patient. To enhance data security, participants proposed to have fingerprint recognition applied as an authentication technique for patients' accounts. Furthermore, to cover various patient profiles and enable ease of use, participants proposed to have the application also in the Albanian language.

While formulating the interview questions, this study considered various technology acceptance models and their corresponding variables, as presented in subsection 7.3.1. Hence, the following sections discuss the findings of this interview study for each variable and model specifically.

7.6.1 Perceived usefulness

Healthcare professionals mentioned several benefits of using the proposed SBNHealth prototype, as follows:

- enhance healthcare services for chronically ill patients (more accurate therapies, better monitoring, continuous communication, detailed overview on patient's condition),
- lower costs related to treatment and management of chronic conditions for patients (fewer hospital visits, no need to travel, fewer phone calls and communication with doctors as this is now provided through the SBNHealth, fewer hospitalization days when patients are kept in the hospital just for monitoring their vital parameters),
- improve patient's life (remote and continuous monitoring, better and detailed communication with the monitoring medical personnel, overview of his/her medical condition),
- increase the effectiveness of care in the healthcare centres, by reducing unnecessary clinical visits, especially during pandemic situations considering people's infections, limited resources, and staff to treat them, and change the institutional approach positively.

From the technical aspect of the proposed sensor-based prototype, all participants perceived it as useful in that it contained the functionalities that enabled them as medical personnel to see remote patients' vital signs either using tables, or graphs. Furthermore, they perceived it as very appropriate to have the possibility to set the range of minimum and maximum values of vital signs, for every patient. This enabled the filtering of patients based on the actual values of their vital signs. Hence, if a measured value was not within this range of minimum and maximum values set by the medical staff, then the patient was listed in the table of critical patients. Therefore, as confirmed by participants, having a filtered list of patients in critical condition helps them to easily access and contact those in need or emergent cases. Healthcare professionals could write an email, call or send a notification to their remote patients. These functionalities were perceived as helpful for communicating with a distance-based patient either through phone, for emergency cases, or through email when the medical staff wanted a written report.

The functionalities to change the measuring interval and real-time transmission were considered to help monitor better the chronically ill patient at a distance because, according to the participants, the patient may not understand and know when a slight increase in any of his/her vital parameters may be a precursor to other complications.

7.6.2 Perceived ease of use

This concept describes the HCPs' perceptions on the ease of use, understandability, and the system's conformity with their needs. Hence, the findings showed that participants perceived the proposed SBNHealth as effortless to use, easy to understand, and simple to view their chronically ill patient's vital signs and communicate with them. This is considered as a positive evaluation taking into account that this study had a variety of users' backgrounds and demographic characteristics.

As confirmed by the healthcare professionals, the proposed sensor-based prototype contained information that was organized logically, was visualized using icons, and was presented in a simpler design, so they did not get lost when using them.

The results of this evaluation study on training needed for the users before implementing the SBNHealth prototype showed that a short training may be needed for elderly medical personnel or those that may want additional clarifications on the system's functionalities.

7.6.3 Job relevance

Healthcare professionals after performing the tasks with the SBNHealth felt that this remote and continuous monitoring prototype is not likely to take a lot of their time to view and communicate with their chronically ill patients and is unlikely to cause additional workload in their everyday activities. They thought they could share a few hours per day or arrange a time interval specifically to view remote patients' vital signs during their working schedule. To provide a better service to distance-based patients, some participants even proposed creating a group of medical staff inside the hospital that would be able to monitor these patients 24-hours.

In this context, it seems that the proposed SBNHealth facilitates the healthcare professional's job as it provides a detailed overview of patients' vital signs, and it does not consume their time, considering their workload and other obligations.

As confirmed by the participants, having a report with a patient's vital signs may have an impact on the prescription of therapies for a group of patients, and they considered it as an advantage for their work. Hence, having a history of values for chronic patients would enable medical staff to provide more accurate and specific therapies, according to the values, and in this way is directly related to their job. Nevertheless, participants emphasized that the changes to patient's therapies may not apply to all their patients, for example, may not apply to ones that have fluctuating values of vital signs, or to patients for whom the medical staff needs more information and the SBNHealth does not offer to them (for example blood sugar, ECG), or that are taking venous therapy.

7.6.4 Behavioural Intention

This evaluation study aimed to understand HCPs' intention to use the SBNHealth platform if it was proposed for application in their health institution. All participants confirmed that they would have worked with a sensor-based platform such as the one proposed. There were some managerial pre-conditions towards this confirmation, such as:

- the management of the clinic would need to approve it first, for the HCPs to be able to use it;
- there should be additional financial support for the medical staff that monitor patients also remotely;
- if there will be a medical staff inside the clinic assigned to monitor patients remotely, then this should be arranged with shifts or with an internal agreement among the healthcare professionals.

According to participants in this study, these managerial pre-conditions seemed to be easier resolved for the private healthcare institutions, while for the public healthcare centre it may be a bit complicated considering that it is a bigger institution that has many hierarchies.

7.6.5 Subjective norm

Healthcare professionals confirmed that the proposed sensor-based prototype would be very useful to apply in private and public healthcare institutions. For the private institutions, participants thought that it would be easier to adopt such platforms considering the good network infrastructure they have and the favourable managerial structures which facilitate the communication. For the public healthcare centre, healthcare professionals considered this to be more challenging.

Furthermore, participants were asked if other colleagues would use such a system, and very positive findings were found. Participants believed that other healthcare professionals would use the proposed SBNHealth prototype.

7.6.6 Task-Technology Fit

The task-technology fit model is closely related to the perceived usefulness of the functionalities that SBNHealth offered to healthcare professionals and job relevance. Hence, according to this theory, the proposed platform would have a positive impact on healthcare professionals' performance and they would use it if it fits with their responsibilities and helped them to fulfil their tasks (Goodhue and Thompson, 1995).

As already discussed in sections 7.7.1 and 7.7.3, and considering findings of this evaluation study whether the terminology of the proposed SBNHealth prototype was related to the tasks, it is clear that the proposed sensor-based prototype fits the needs of healthcare professionals to provide remote and continuous monitoring to their chronically ill patients. Furthermore, the proposed SBNHealth contains most of the functionalities that healthcare professionals used to have in their wired-based platforms inside the clinic, and additional new functionalities (i.e., set the range of minimum and maximum for every vital sign, contact the patient directly from the platform, send a notification, access values of vital signs remotely and in real-time) that as participants confirmed, would further facilitate their work and help offer better health services to their patients.

As suggested by the healthcare professionals, SBNHealth would enable the patient to decide with whom he/she wants to share their medical information. Hence, once the patient authorized a member of the medical staff, he/she received an email with the patient's unique code and only in this way was able to add the patient for monitoring using the web platform of the SBNHealth. This was another functionality that participants evaluated to fit their tasks in protecting patients' information and limiting unauthorized access.

7.6.7 Performance expectancy

Performance expectancy defines the degree to which healthcare professionals, in this case, perceived the SBNHealth prototype to help them and improve their performance (Venkatesh et. al., 2003). The findings showed that for some participants it was difficult to foresee how the proposed sensor-based platform would impact their performance, as they needed to see it implemented and use it more concretely in their healthcare institution. However, other participants provided examples of how the proposed SBNHealth would improve and facilitate their work, especially in remote and continuous monitoring as they were not doing it currently. Even though they were monitoring the patients at a distance using some wired-based platforms, they could not communicate and see his/her values of vital signs at a distance and, in this context, SBNHealth provides advantages to them. Therefore, the participants confirmed that the proposed platform contains sufficient information on a patient's vital signs that would help accomplish and facilitate the medical staff tasks that they need for remote and continuous monitoring. As such, they considered the SBNHealth prototype to increase their job performance.

Regarding the technical aspect of the performance of the proposed SBNHealth prototype, healthcare professionals perceived the platform offered information on the actions they were performing with it; hence they were informed about the progress of their actions. Furthermore, from their experience with the tasks on the SBNHealth, participants evaluated the platform to have a good performance.

7.6.8 Social influence

Participants perceived that the proposed SBNHealth prototype will provide an innovative solution to them and their clinic considering that such platforms are not yet available in Kosovo, or even in the Balkan region. Furthermore, they confirmed their intentions (subsection 7.6.4) to use the proposed sensor-based prototype considering the increased job performance (subsection 7.6.7), the perceived usefulness, and ease of use (subsections 7.6.1 and 7.6.2).

The results of this evaluation phase as to whether other colleagues of participants would use the proposed SBNHealth prototype, either in the private or public healthcare institutions, revealed positive expectations that other healthcare professionals would also use the proposed sensor-based platform for remote and continuous monitoring of chronically ill patients.

7.6.9 Truth-telling

The findings of the first interview study with healthcare professionals (chapter 5) helped to identify a new variable that was related to technology acceptance in the healthcare domain. Truth-telling was identified as a very important factor that needs consideration when researching the application of digital technologies into healthcare on which the patient has direct access to his/her medical information.

In the proposed SBNHealth prototype, the patient may view his/her values of the vital signs directly on the mobile application. Furthermore, the patient can take new measurements and share them with their medical personnel. In this context, healthcare professionals had different opinions.

Some participants thought that a patient's access to his/her vital signs may affect their medical condition when the values are not within the normal range. They may cause stress or discomfort for the patient and, in this way, trigger further increases in the values. The other group of participants emphasized that this may depend on the patient's level of education, experience in reading values of vital signs, or knowledge about his/her disease.

Nevertheless, SBNHealth offered the possibility for healthcare professionals to set the minimum and maximum values for every vital sign in the web platform. Hence, this range of normal limits is also shown to the patient in their mobile application and, in this way, the patient may see if the measured value through the sensor-based prototype, is within the range of limits set by the healthcare professional.

Besides this aspect, participants of the evaluation phase considered that patient's access to vital signs may facilitate their remote monitoring, taking as an example the pandemic situation, in which almost every house had i.e., at least a pulse oximeter and was able to read values of oxygen saturation which was considered an important symptom of infection with Covid-19 during this time.

7.7 Strengths and limitations

This phase of the research aimed to evaluate the proposed sensor-based prototype that enabled HCPs to monitor remotely and continuously their chronically ill patients. The qualitative research method was used to gain an in-depth understanding of the views of participants on various aspects related to the proposed SBNHealth functionalities. However, this research had some limitations.

First, as this is a small-scale interview study, the findings may not be generalizable to a wider population, i.e., the HCPs within Kosovo. Nonetheless, the purpose of this phase of research was to provide healthcare professionals with a sensor-based prototype that was implemented based on their needs gathered during the first phase of interviews (chapter 5), and after that investigate their comments, feedback, and evaluate the proposed SBNHealth prototype. Hence, given the detailed analysis, discussion, and participant's feedback, these findings might be applicable, or transferable, to similar groups of participants that may use the proposed platform.

Secondly, the HCPs had no experience with similar sensor-based platforms that offered them continuous and remote monitoring and communication with their chronically ill patients. However, participants had some predefined tasks to perform with the proposed prototype, while the researcher was playing the role of the patient and sharing the vital signs to the web platform, for the medical personnel to view them and evaluate.

Despite the limitations mentioned above, the findings presented in this study provide a positive evaluation of the functionalities that the proposed sensor-based prototype offered to HCPs, its clinical usage, and its impact on various aspects of healthcare practice as discussed in this chapter. Furthermore, this study evaluated the proposed SBNHealth platform considering various constructs of technology acceptance variables, including the truth-telling variable that emerged from the findings of our first interview study. Hence, the results of this study enable the enhancement of the proposed prototype, considering also participant's suggestions, and provide information for system developers of sensor-based platforms on the functionalities that healthcare professionals perceived as needed and useful to them for remote and continuous monitoring of their chronically ill patients.

7.8 Conclusions

The information presented throughout this chapter contributes further to the sensor-based platforms area by presenting an evaluation interview study with healthcare professionals' feedback and opinions on the proposed prototype. The formulation and design of this study based on technology acceptance variables, and the evaluation of the truth-telling factor that emerged from the findings of the first interview study, presented important considerations for system designers, and researchers towards studies on adoption and acceptance of sensor-based technologies in the healthcare settings.

Additionally, this evaluation interview study contributed to answering more concretely this thesis research questions (subsection 2.8.3) which could not be clearly addressed from the first empirical research (chapter 5). Further details on the answers to the research questions of this interview study and the key findings are elaborated in the following subsections.

7.8.1 Research questions outcomes

This evaluation interview study aimed to address and answer the emerging research questions presented in section 7.2, which are closely aligned with overall thesis research questions (subsection 2.8.3). The following paragraphs provide details on how each of the below questions was addressed.

1. To what extent would healthcare professionals apply the proposed prototype of a sensor-based platform for remote and continuous monitoring of their chronically ill patients in developing countries, Kosovo as a case study?

   Healthcare professionals provided detailed explanations on how they could use the proposed sensor-based prototype in their daily work and for remote monitoring of their patients, in subsection 7.5.4.1.

2. How can the proposed prototype of the sensor-based platform affect healthcare professionals' daily work and patient's life?

   This research question was addressed in detailed information presented throughout the subsections of subsection 7.5.5.

3. How likely is the proposed prototype to be implemented in the private and public healthcare centres of a developing country, i.e., Kosovo?

   This evaluation interview study investigated the HCPs' opinions on how the proposed sensor-based prototype would affect the private (subsection 7.5.4.2) and the public (subsection 7.5.4.3) healthcare institutions. The answers to this question can be found in the respective subsections.

4. What may be the benefits of applying the proposed prototype of the sensor-based platform for the healthcare system of a developing country, Kosovo in this case?

   This research question is addressed in subsection 7.5.5.7.

5. What may be the factors that may limit the successful application of the proposed prototype of the sensor-based platform, from the healthcare professional's perspective?

   The factors that may challenge the successful application of the proposed sensor-based prototype are briefly presented in subsection 7.5.6.

6. What are healthcare professionals' suggestions to further advance the proposed prototype of the sensor-based platform?

   After performing the tasks with the proposed sensor-based prototype, the participants had some proposals related to additional parameters to monitor, additional information to present, such as gender, weight, or the system to be translated in other languages. All these details are presented in subsection 7.5.7.

7. What are the strengths and limitations of the proposed sensor-based prototype?

   The details about the functionalities of the proposed sensor-based prototype were evaluated through the categories of questions related to the suitability for performing the tasks or the functionalities that the HCPs needed, the self-descriptiveness, the controllability, the conformity with user's expectations, and the suitability for learning. All these details address this research question in subsection 7.5.8 – 7.5.12.

Hence, to summarize the findings of this evaluation interview study, the following subsection provides its key contributions.

7.8.2 Key findings

Healthcare professionals who used the proposed SBNHealth prototype overall had a very positive evaluation of the benefits, functionalities, and clinical usage of the platform, for both private and public healthcare institutions. The functionalities that the proposed sensor-based prototype had, were perceived as useful, easy to learn, fit with the healthcare professionals' tasks, and would improve their performance. Nonetheless, some factors may challenge the successful implementation of the proposed sensor-based prototype, as follows:

a. there should be a managerial willingness from the healthcare institutions to use and provide a remote monitoring platform for their chronically ill patients,
b. management of healthcare institutions should arrange the monitoring personnel also inside the clinic, and their financial aspects for providing distance-based monitoring,
c. doctors and remotely monitored chronically ill patients should arrange a communication channel to understand each other and work together for better monitoring.

From the detailed discussion on the technology acceptance variables, it can be concluded that the ease of use seemed to affect the job relevance and behavioural intention variables, as healthcare professionals perceived the SBNHealth as a helpful tool for clinical usage to monitor chronically ill patients remotely and continuously, and as easy to apply so that it will not take a lot of their time, and it will not cause workload but, on the contrary, would facilitate their work by providing a detailed overview on the patient's vital signs for longer period of time. Further to this, these variables affect the performance expectancy of healthcare professionals in a positive aspect, as the findings showed.

The perceived usefulness is another variable that, according to the findings of this evaluation study, affected various aspects of treating and managing chronically ill patients using the proposed sensor-based prototype. Hence, the results showed that participants perceived the SBNHealth to be useful in providing detailed patient's condition, filtering critical patients, enabling medical staff to add a patient and set the range of minimum and maximum values for every vital sign, change patient's data transmission mode, and real-time monitoring even remotely. These benefits of the proposed sensor-based prototype, according to the participants, may reduce hospital visits (unnecessary ones when patients were visiting to measure a single vital parameter, e.g., blood pressure, or consulting with the doctor), shorten hospitalization days (for patients that were hospitalized just for monitoring their conditions), lower treatment costs related to chronic diseases, reduce unnecessary phone calls and travel expenses for patients, enable patients have an overview of their medical condition and in this way improve their life.

The following chapter will discuss and critically synthesize the findings of both interview studies, the ones presented in chapter 5 and the ones elaborated in this chapter. Furthermore, chapter 8 will provide the overall thesis discussion, the integration of the findings on both interview studies, and the strengths and limitations of this research work.

Chapter 8 Discussion

8.1 Introduction

Two earlier chapters (5 and 7) in this thesis presented two qualitative studies conducted with healthcare professionals in a private healthcare institution, the American Hospital, in a developing country, Kosovo. The first interview study (chapter 5) investigated and presented healthcare professionals' attitudes and perceptions on using a sensor-based platform for remote and continuous monitoring of their chronically ill patients. The second interview study (chapter 7) elaborated the healthcare professionals' feedback and opinions on the proposed and implemented sensor-based remote monitoring prototype, as part of this research project. Both of these interview studies used theoretical frameworks based on technology acceptance variables from various models, such as the TAM, TAM2, UTAUT, and TTF, as elaborated in section 2.5.

This chapter will compare and critically discuss the findings of the two studies to contribute to the research and provide knowledge in the area of technology acceptance in healthcare settings of developing countries, considering Kosovo as an example of such a region. As such, this chapter will discuss the findings of the two interview studies using within-method triangulation in section 8.2. Further to this, the overall findings composed from this process will be compared and critically analysed considering similar studies that exist in the literature, in section 8.3. Section 8.4 will discuss the trustworthiness aspects of this research project. The strengths and limitations are elaborated in section 8.5. Finally, section 8.6 concludes the discussions of this thesis.

8.2 Within-method triangulation

Triangulation was used to gain a deeper understanding of the findings of the two interview studies that aimed to investigate healthcare professionals' attitudes, perceptions and get their feedback on the proposed sensor-based prototype. The findings of the first interview study revealed that healthcare professionals did not have experience with sensor-based platforms for real-time and distance-based monitoring of their patients; hence, some research questions of this thesis could not be answered in detail. Therefore, the second interview study and the proposal of the SBNHealth prototype (chapter 6) enabled a wider and more complete picture of acceptance and adoption of a sensor-based prototype for remote and continuous monitoring of chronically ill patients in Kosovo. The aim here is to use triangulation for confirmation and completeness of the findings presented from both interview studies.

As both research studies utilised qualitative interviews, within method triangulation will help to better and more thoroughly analyse and integrate the results from interview study 1 and interview study 2, and, in this way, develop a more comprehensive understanding of the phenomena. For a more detailed evaluation, this section is divided on the discussion of practical implementation aspects of the sensor-based platforms as presented in subsection 8.2.1 and another detailed discussion based on technology acceptance constructs as elaborated in subsection 8.2.2.

8.2.1 Practical implementation aspects

This section will provide a detailed overview of the practical implementation aspects discussed in both interview studies. Table 8.1 summarizes the most important aspects that healthcare professionals reviewed on sensor-based platforms (Interview study 1) and later evaluated on the proposed sensor-based prototype (Interview study 2).

Table 8.1 Application of sensor-based platforms for remote and continuous monitoring of chronically ill patients: practical implementation aspects

Interview study 1: HCP attitudes and perceptions towards SBN for remote and continuous monitoring of chronically ill patients		**Interview study 2: Evaluation of the proposed SBNHealth prototype**	
Aspect	**Findings of the study**	**Aspect**	**Findings of the study**
Acceptance of sensor-based platforms	Most of the participants (25 out of 26) expressed a positive attitude in applying sensor-based platforms for remote monitoring of their patients. They confirmed that it would be a relief for them to have the patient's history and that would also influence the therapies or medication they provided. One participant confirmed the benefits of such platforms; however, he was more concerned about the monitoring staff who would assist remote patients.	Usage of the proposed sensor-based prototype	Most of the participants (six out of eight), revealed their positive attitudes to use the proposed SBNHealth for monitoring their chronically ill patients. There was one participant who needed to see the platform implemented, to comment on its usage; and another one that declared that his usage of the proposed sensor-based prototype, would depend on the financial support provided for remote and continuous monitoring of chronically ill patients.
Advantages of digital technologies (including SBN) in healthcare	- Possibility to set the measuring interval and automatic measurement of patient's vital signs - Provision of alarms and red marks in the monitoring screens - Possibility to summarize and display all the measured values in a small screen located at the nurses' desk - The option to get a printed report as a summary of a patient's condition for the previous 24 hours	Advantages of SBNHealth in healthcare	- Possibility to change the transmission mode of vital signs (real-time, every two hours, and on patient willingness) - Possibility to add the range of maximum and minimum values for every vital sign - Filtering of critical patients on the Home page - Possibility to generate a report of measurement for longer periods of time
Benefits of remote and continuous monitoring using	- Continuous monitoring - Time-saving - Present the information that healthcare professionals need	Benefits of remote and continuous monitoring using	- Continuous and real-time monitoring - Time-saving - Facilitates and improves the work of HCP - Patients treated and monitored better

sensor-based platforms	- Patients treated and monitored better - Enhanced healthcare services - Safety feeling for the patient	proposed sensor-based prototype	- Communication with remote patients - Reduces the number of visits - Reduces costs - Avoids unnecessary phone calls - Saves traveling time - Reduces traveling expenses
Monitoring vital signs using sensor-based platforms	HCPs confirmed that they needed the following vital signs for remotely monitoring chronically ill patients: blood pressure (systolic/diastolic), oxygen saturation, heart rate, temperature, and respiratory rate. Some participants also proposed using the sensor-based platforms for monitoring diabetic patients, and hence, have the blood glucose level as well. Further to this, the HCPs suggested that the values of chronic parameters are variable (i.e., different when the patient is standing, sleeping, running, or walking, or can be affected by the emotional or physical state of the patient).	Monitoring vital signs using SBNHealth prototype	Participants confirmed it was important to have five vital signs that they could monitor in their remote chronically ill patients: blood pressure (systolic/ diastolic), oxygen saturation, heart rate, and respiratory rate. The temperature was missing and a doctor suggested that it would be good to have it. Furthermore, two participants suggested that it would be good to have values of blood glucose too, even if it is not measured using the sensor-based platform, but have the possibility on the SBNHealth, for the patient to add it (i.e., measure using his/her device and then entering the values on the SBNHealth). While performing the tasks with the system, the researcher [AB] who was playing the role of the patient, was speaking and performing measurements of vital signs at the same time. Hence, the HCPs noticed that some values of the vital signs were altered, and this relates to the variability of parameters based on the patient's physical or emotional condition.
Range of critical values of vital signs	Participants discussed the variable range of critical values based on the patient's age, or the condition of various organs of the human body. Hence, they could not perceive how to set a range for every	Range of critical values of vital signs	Using the SBNHealth the healthcare professionals were able to set the critical range of values (i.e., the minimum and maximum values) for every vital sign that the platform had (i.e., blood pressure, oxygen

for chronically ill patients	vital sign that would apply to all chronically ill patients.	for chronically ill patients	saturation, heart rate, and respiratory rate) while adding the patient for monitoring. This functionality was evaluated as very much needed and appropriate.
Frequency of measuring vital signs using sensor-based platforms	The HCPs confirmed that they used their digital monitoring platforms inside the hospital to measure a patient's vital signs every two hours. When the patient's condition was critical, they were measuring all the time. The same logic was applied when using Holter monitors for remote patients for 24 up to 72 hours of monitoring. The vital signs, in this case, were measured all the time.	Frequency of measuring vital signs using SBNHealth	The SBNHealth offered three data transmission modes: real-time, every two hours, and on patient willingness. The healthcare professionals from the web portal of the platform could change the data transmission mode based on a patient's condition. The remote patient, in this case, was receiving a notification and could accept or decline the new data transmission mode requested from the monitoring doctor. These functionalities were evaluated as very appropriate and similar to what participants were used to having, and they had no other suggestions on how to improve them further.
Communication with remote patients that were under monitoring, using SBN	Participants confirmed that while monitoring remote chronically ill patients using Holter monitors, they could not see the recorded vital signs, or communicate with the patient, only if the patient was sending messages through VoIP applications such as Viber™ or WhatsApp™.	Communication with remote patients that were under monitoring, using SBNHealth	HCP could see a patient's vital signs and contact ones that were under monitoring using email, phone, or sending notifications, using the web portal of the SBNHealth prototype. These methods were evaluated as feasible and ones that could be used most of the time.
Impact of the sensor-based applications	- Clinical-decision making - Number of visits - Hospitalization days - Financial aspects - Patient life	Impact of the SBNHealth prototype	- Clinical-decision making (patient's therapies) - Number of visits - Hospitalization days - Costs related to chronic diseases - Patient life - Working schedule of healthcare professionals - Workload of healthcare professionals - Healthcare sector of a developing region

Presentation methods of gathered vital signs from the sensor-based platforms	- Tables with numerical values - Graphs with details	Presentation methods of gathered vital signs using SBNHealth	- Tables with numerical values (date and time, and each vital sign value presented in a separate column) - Graph with the possibility to hover over it and show the value of the vital sign at the date-time interval
Challenges for a successful application of sensor-based platforms	- Cost of the proposed platform - Lack of national health insurance - Patient collaboration - Artefacts of the SBN platform - Wireless communication technology - Charging method of the platform	Challenges of the proposed SBNHealth prototype	- Patient and doctor cooperation for remote monitoring through SBNHealth - Managerial aspects of the healthcare institutions to accept the application of the SBNHealth - Financial support for the medical staff who monitor patients remotely - Responsible medical staff to monitor patients from the hospital using SBNHealth
Drawbacks of existing SBN applied in the American Hospital	- Not being able to access patient information online - Data accuracy - Wires of the devices - Possibility for the electrodes to get removed and the system to provide a false alarm - High cost	Drawbacks of the proposed SBNHealth prototype	- Data accuracy

In the first interview study, participants talked in general about acceptance of any sensor-based platform, while in the second interview study they evaluated the usage of the proposed sensor-based prototype. Hence, as shown in Table 8.1, for the first interview study, the acceptance of SBN platforms is considered in parallel evaluation with the usage of the proposed SBNHealth aspect as elaborated in the second interview study. The findings of both these aspects for sensor-based platforms showed that the majority of the healthcare professionals had positive attitudes to using such platforms for continuous and remote monitoring of their chronically ill patients. There were participants in both studies who expressed their concerns in this regard, and the same were discussed also as challenges for successful implementation of sensor-based systems, as presented in Table 8.1.

While comparing the advantages that emerged from the findings on both interview studies, it is clear that SBNHealth offered more possibilities to healthcare professionals compared to their existing wired sensor-based platforms that they used. Hence, the additional functionalities that the SBNHealth provided to them were the possibility to communicate with the patient remotely (via email, phone, notifications), continuous and real-time monitoring of the patient's vital signs, the possibility to change the transmission mode of the vital signs remotely, and the possibility to generate a report of measurements for longer period of time (section 6.7). This is further supported also by Viderman et al., (2022) that concluded the application of sensor-based platforms such as wearables, will assist the medical personnel considering the increasing prevalence of chronically ill patients.

The identified advantages were closely related to the benefits that healthcare professionals mentioned to have from the remote and continuous monitoring of their patients using the SBNHealth prototype. As presented in Table 8.1 there were very similar findings on the advantages and benefits of sensor-based platforms on both interview studies, however, in the second interview study as healthcare professionals had the chance to perform tasks with the proposed SBNHealth prototype (chapter 6) and see a patient's vital signs, they had a clearer experience of the benefits that this platform could bring to them and their chronically ill patients. This is also supported by the findings of a recent study by Verrillo et al. (2019), which found a 7% decrease in the rate in complications of health conditions for the continuous vital sign monitored patients and a significant decrease in the number of cases of patients that were transferred to intensive care unit.

During the first interview study, when discussing the vital signs that healthcare professionals needed to monitor in their remote chronically ill patients (subsection 5.5.6), they mentioned the blood pressure (systolic/diastolic), oxygen saturation, heart rate, temperature, and respiratory rate. For diabetic patients, participants also mentioned blood glucose. Besides the temperature and blood glucose, the rest of the parameters were incorporated into the SBNHealth. However, participants during the second interview study proposed again to have these two parameters as they needed for remote and continuous monitoring of their chronically ill patients. This will be considered as a future improvement for the SBNHealth platform (section 9.5), as for measuring the blood glucose the platform may need special sensors or maybe the possibility for the patient to enter the values manually while using another device to measure them, as suggested by participants. Nevertheless, it was clear that the findings from both interview studies, the proposals of the participants, again overlap on the vital signs that they need for remote and continuous monitoring.

The normal interval of the values of chronic parameters was discussed during the first interview study, and the healthcare professionals raised their concerns on how a sensor-based platform could detect when a patient was in a critical situation, or when his/her values of the vital signs were not within the normal range. Hence, the SBNHealth provided the possibility that, for every patient, the medical staff could set the range of critical values (subsection 6.7.2.2). If this range was not set, then the platform had its predefined values of every vital sign it showed based on the literature data as discussed in subsection 2.3.3.

When a value of a vital sign was not within the normal range, then the patient was listed in the table of critical patients on the *Home page* of the SBNHealth (subsection 6.7.2.1), where the monitoring doctor could easily see the detailed overview of the vital signs and contact the patient.

The critical values of the vital signs also indicate the frequency of measuring them. Hence, as shown in Table 8.1, the frequency of measuring vital signs using sensor-based platforms, provided similar results from both interview studies. Nevertheless, the SBNHealth offered more flexibility to medical personnel to change the data transmission mode for remote patients that they had under monitoring (Subsection 6.7.2.4). The functionality of the SBNHealth, *Mode 1: Patient willingness*, presented the transmission of the gathered patient's vital signs when he/she was not feeling well and wanted to consult the monitoring medical personnel, remotely (subsection 6.4.2). This was not possible using existing digital technologies that the participants were using. Further to this, the SBHealth platform allowed the patient to decide whether to accept or decline the changes to data transmission modes requested from the monitoring doctor. The possibility for the patient to decide on a data-sharing method was implemented to ensure the ethical aspects so that the patient was aware and provided consent while transmitting his/her values of the vital signs to the medical personnel.

The healthcare professionals confirmed that they could not see patients' vital signs, or communicate with them while monitoring at a distance using their sensor-based platforms, i.e., Holter monitors (subsection 5.5.3). Nevertheless, while using SBNHealth they could see the patients' values based on data transmission mode, i.e., every two hours, real-time, or when the patient was transmitting them; and could contact the patient by sending email, or making a phone call, directly from the web-portal of the SBNHealth. These functionalities were evaluated as helpful to the medical staff especially in cases when they wanted to contact critical patients more urgently by phone, or when they needed to write a report of the patient's condition and send it to their email.

The findings of both interview studies revealed a diversity of aspects when considering different impacts of the sensor-based platforms. During the first interview study, the clinical-decision making was considered to be facilitated by the use of the sensor-based applications, as it would provide healthcare professionals with a report of measurements and critical values that might have an impact on the patient's therapy and their clinical overview (subsection 5.5.8.4). Nevertheless, during the second interview study, the participants confirmed that the application of the proposed SBNHealth prototype could affect the therapies of patients, considering that now they could access a history of measurements of vital signs; however, this might not apply to all chronic patients (subsection 7.5.5.3). Hence, the participants mentioned some limiting factors that could prevent them from providing a prescription of therapies electronically and were related to the patient's condition, for example, when a patient's vital signs were fluctuating, or when the patient was using venous therapy. Therefore, after using the actual sensor-based prototype HCPs were able to provide more detailed feedback and examples on the impact of such platforms on clinical-decision making.

Regarding the impact of a sensor-based platform on the number of hospital visits, the results of the first interview study showed different opinions of HCPs (subsection 5.6.8.4). There was a group of participants who supported the idea of the increased number of hospital visits, as many chronically ill patients are diagnosed at an early stage of their disease; and the other group of healthcare professionals who thought the application of SBN would reduce the number of patient visits to the hospital, as they would be monitored remotely. Nevertheless, in the second interview study, participants confirmed that the application of the SBNHealth prototype would reduce patient visits to clinical centres (subsection 7.5.5.4). This might be related to healthcare professionals' experience of performing tasks and using the SBNHealth prototype, which was not the case during the first interview study. Nevertheless, the literature data showed that sensor-based platforms may reduce the hospital visits and hospital stay (Viderman et al., 2022).

The findings from both interview studies on the impact of sensor-based platforms on the hospitalization days gave similar results. Participants thought that the application of sensor-based platforms could prevent unnecessary hospitalizations or possibly shorten the hospitalization time; however, this might not apply to critical patients that need hospitalization and clinical surveillance.

The financial aspects related to treating and managing chronic diseases were discussed as an important factor that also affects the successful implementation of SBNs for remote and continuous patient monitoring. Similarly, with some other aspects of the impact discussed above, the HCPs, after using the proposed sensor-based prototype and seeing the functionalities that it offered them and their patients through the mobile platform, confirmed that it would have an impact on the costs related to chronic diseases, and it would provide a reduction of costs, both overall and in the long term.

Reduced costs have an impact also on the patient's life. Hence, as discussed by the HCPs, there were ways in which the application of sensor-based platforms could potentially affect the patient's life by offering better treatment, saving time, and enhancing their quality of life, and reducing the number of deaths (subsections 5.5.8.4 and 7.5.5.6). Nevertheless, in the first interview study, there were some participants (two out of 26) who believed that the application of an SBN could create concerns for patients. Very similar findings were presented also in the second interview study. Hence, some participants considered that giving a patient access to his/her vital signs could affect their medical condition, i.e., causing stress when the values of the vital signs were not within the normal range. Nevertheless, as confirmed by HCPs, this may depend on the patient's level of education, experience in reading values of vital signs, or knowledge about his/her disease.

Two other aspects that were discussed in the second interview study with HCPs, were related to the impact of the proposed sensor-based prototype on their working schedule and workload (subsections 7.5.5.1 and 7.5.5.2). The participants confirmed the proposed prototype did not take a lot of their time to access and view a patient's vital signs. Hence, they suggested that they could allocate a time slot within their working schedule for monitoring distance-based patients and communicating with them. In this way, the majority of participants (six out of eight) confirmed that the proposed SBNHealth seemed not to overload them, considering that it did not take a lot of their time. Further to this, the HCPs confirmed that the application of the proposed SBNHealth prototype might:

- increase the effectiveness of care;

- reduce unnecessary clinical visits especially in pandemic situations considering people's infections, limited resources, and staff to treat them; and
- change the institutional approach positively, if the institutions will be willing to use them.

These are important dimensions to help developing countries, considering the challenges they face, especially when there are limited resources to treat and manage the increasing number of chronically ill patients.

The challenges from the findings of the first interview study (subsection 5.5.8.8) differed slightly from those of the second interview study (subsection 7.5.6) as presented in Table 8.1, and this may be considered as expected. In the first interview study, the HCPs listed the cost of the sensor-based platform as an important factor that may limit the successful implementation of such applications into healthcare systems within Kosovo. This was not discussed as a challenge during the second interview study, as the web portal of the SBNHealth was accessible from any desktop or laptop that the HCPs were using, and the sensor-based platform was developed as a mobile application to record vital signs and was installed on an Android device. Hence, there were no additional devices that users needed to buy to have remote and continuous monitoring using the proposed SBNHealth. Nevertheless, as suggested by participants in both interview studies, the sensor-based platform may be suitable for the patients to wear, if it was in the form of a watch or wrist that would be attached to a patient's body. Hence, for such a case, the system designers should consider proposing a sensor-based device that would be cost-effective as suggested from the findings of the first interview study. Another challenging factor that was discussed during the first interview study, was the lack of national health insurance that still (2021) remains an open issue for Kosovo citizens. As the interviews were conducted in a private healthcare institution, participants talked about the expenses that patients have while being treated there.

Besides the financial aspects that were considered important to be taken into account, the patient and doctor collaboration was another aspect that participants thought should be arranged for a successful implementation of sensor-based platforms. According to the participants' opinions, both of them need to understand how to manage, communicate and transfer gathered data between each other, and hence have a form of cooperation. In this regard, Prgomet et al., (2016) identified similar concerns regarding limited interactions between the healthcare professionals and nurses, and reported this as a challenge for applying digital technology in healthcare.

The artefacts were considered as a challenging aspect of SBNs during the first interview study, and as a drawback of the proposed SBNHealth prototype during the second interview study. Hence, HCPs needed accurate values of the vital signs to provide reliable feedback to remote patients. In the case of the SBNHealth prototype, there were two cases that the researcher [AB] was speaking while making the measurement, and the recorded values of the blood pressure that were transmitted to the remote monitoring doctor were incompatible. Therefore, as the patient would be at a distance, the medical staff might not be aware that he/she was talking, running, standing, or resting when performing the measurement i.e., because the monitoring doctor would be remote, they would only see the recorded values. In this regard, the HCPs proposed to have the patient's position (i.e., standing, running, before/after exercise) when performing the measurement as additional functionality to the proposed SBNHealth prototype.

During the evaluation phase of this research project, as HCPs were using the proposed prototype, they raised two further challenges as indicated below:

a. there should be an agreement with the managerial level of the healthcare institutions to use and provide a remote monitoring platform to their chronically ill patients, and
b. there should be a form of managerial organization to financially support the medical staff who provide distance-based monitoring and arrange monitoring personnel also inside the clinic to help in this regard.

Hence, there were various aspects discussed in both interview studies related to the attitudes, adoption, usage and successful implementation of sensor-based platforms for remote and continuous monitoring of chronically ill patients in Kosovo. The healthcare professionals provided different perspectives and proposals to be considered in future studies and revisions of the proposed SBNHealth prototype, as presented in section 9.5.

The interview studies in this thesis were based on theoretical frameworks that used technology acceptance constructs. Hence, the following subsection will integrate the findings of both qualitative studies and provide a detailed discussion on technology acceptance constructs that were considered.

8.2.2 Technology acceptance constructs

This subsection will provide a detailed overview of the technology acceptance constructs (section 2.5) discussed in both interview studies. As presented in Table 8.2, both qualitative studies discussed various aspects of technology acceptance in healthcare settings.

While considering findings from both interview studies on the perceived usefulness aspects, it was clear that the same participants, after using the proposed SBNHealth prototype, could provide more detailed feedback and opinions on the useful aspects of a sensor-based platform in the healthcare setting. Hence, findings of the first interview study, in which nurses showed a mistrust of digital technologies, contrasted with the second interview study, in which they perceived the proposed prototype to help medical staff provide more accurate therapies, improve their performance and facilitate their work by having a report of measurements for the patient’s vital signs over a longer period of time. Moreover, other functionalities that they used in SBNHealth, such as changing data transmission mode, filtering critical patients, communicating with remote patients, and real-time data transmission, were considered to be helpful for remote monitoring of their patients.

The perceived ease of use aspects gave similar findings on both interview studies. Healthcare professionals perceived sensor-based platforms (either those that they were already using or the SBNHealth prototype) as effortless to use, easy to understand, and useful to provide information on chronically ill patients. The participants confirmed that training was provided and may be needed also in the case of SBNHealth for elderly medical personnel or those who might want additional clarifications on the system’s functionalities. This was also proposed by Malasinghe, Ramzan and Dahal (2019) in their study, in which participants proposed to have additional experience and training with the digital technologies in order to increase their comfort in using the platform.

Participants in both interview studies intended to use sensor-based platforms for remote and continuous monitoring of their chronically ill patients. Their behavioural intention aspects were related to viewing patients' conditions in a more detailed manner while also having access to them remotely. Nevertheless, some managerial pre-conditions would have to be met and would be important to consider for HCPs to be able to use sensor-based platforms. These pre-conditions were related to the managerial approval for such platforms to be implemented and used in healthcare institutions, the financial support for medical staff that would provide remote monitoring, and the arrangement of monitoring personnel also inside the clinic to help in this regard.

Both interview studies confirmed that the application of sensor-based platforms into healthcare settings will improve the performance expectancy aspects of medical staff. Hence, healthcare professionals even provided examples of how the actual usage of sensor-based applications would help them accomplish their tasks, facilitate patient monitoring and improve their job performance. These factors were closely related to the functionalities that the sensor-based platforms, for example, the SBNHealth prototype, offered to medical staff. Hence, the performance expectancy and actual usage aspects also affected the job relevance aspects. In this context, participants described how the functionalities that the SBNHealth offered to them would impact patients' therapies, medical conditions, and in this way facilitate their work. Furthermore, considering their experience with the proposed sensor-based prototype, the healthcare professionals confirmed that this platform may not take a lot of their time or overload them, which are important job relevance aspects for the participants.

Table 8.2 Application of sensor-based platforms for remote and continuous monitoring of chronically ill patients: technology acceptance constructs

Construct	**Findings of the first interview study:** HCP attitudes and perceptions towards SBN for remote and continuous monitoring of chronically ill patients	**Findings of the second interview study:** Evaluation of the proposed SBNHealth prototype
Perceived usefulness	Doctors perceived sensor-based platforms as useful for applying and improving their performance towards monitoring the vital signs of their remote chronically ill patients. Nurses showed some examples of mistrusting digital monitoring systems, as in several cases they were using manual devices to measure the same parameters (i.e., blood pressure, pulse, oxygen saturation) they were measuring using the wired-based digital monitoring system inside the clinic.	All participants perceived the proposed SBNHealth prototype as useful to enhance healthcare services, lower costs related to treatment and management of chronic conditions, improve patient's life, and increase the effectiveness of care in healthcare centres.
Perceived ease of use	The healthcare professionals seemed to have adopted the existing systems (wired digital monitoring system used inside the clinic, Holter monitors, and CGM used for remote monitoring) easily and for them the monitoring of patients' vital signs using these platforms was effortless. Participants confirmed to have training from the system providers, before using such platforms.	Participants perceived the proposed SBNHealth as effortless to use, easy to understand, and simple to view their chronically ill patient's vital signs and communicate with them. They found the information easily located in the platform, logically organized, simply visualised using icons, so that they did not get lost when using it. Furthermore, the HCPs thought that some short training may be needed for older medical personnel or those who might want additional clarifications on the system's functionalities.
Behavioural intention	Participants expressed their interest in using sensor-based platforms for remote and continuous monitoring of chronically ill patients.	Similarly, the HCPs, when considering the benefits of the proposed SBNHealth prototype, confirmed that they would have worked with such a platform, given that some managerial pre-conditions are met (as discussed above).

Performance expectancy	The healthcare professionals confirmed that the application of digital technology affected their job performance and helped them complete tasks easily.	Most of the participants (six out of eight) perceived the SBNHealth prototype to improve their job performance, while two of them needed to see the platform implemented in their institution and use it more concretely to provide opinions on this.
Job relevance	The perceived usefulness, ease of use, and performance expectancy had a direct impact on job relevance aspects of sensor-based platforms. The HCPs confirmed that a report of measurements with a patient's vital signs would help them in the prescription of therapies and arrangement of patient's visits to clinical centres.	Participants, after performing the tasks with the SBNHealth prototype, confirmed that it would not take a lot of their time to view and communicate with a remote patient, and it would not overload them. Furthermore, they confirmed that the functionalities of the platform were relevant and would facilitate the medical staff's job.
Social influence	Participants were considering their healthcare institution to use the most advanced digital platforms in the region. Hence, they were proud to have sensor-based systems such as Holter monitors or CGM for their remote patients. Therefore, they were willing to keep this functionality and adopt other advanced sensor-based platforms.	The HCPs considered the proposed SBNHealth prototype as an innovative solution for remote and continuous monitoring of their chronically ill patients, taking into account that such platforms were not yet currently used in other healthcare institutions in Kosovo, or the SEE developing countries. Furthermore, the participants also thought that other colleagues, medical staff, would use the proposed sensor-based prototype.
Truth-telling	Participants confirmed that, in some cases, they do not tell the patient about the values of his/her vital sign, for example, when the values are high, or when the patient is not well. In these cases, medical staff preferred to speak with family members and inform them. However, as confirmed, there were exceptions, e.g., if a patient was more informed about his/her condition or disease, or was educated enough to understand the values of the vital signs.	As the patient will have his/her mobile application of the SBNHealth prototype, he/she will have access to the values of the vital signs. According to some HCPs, this may affect a patient's medical condition when the values are not within the normal range. However, other HCPs thought this might depend on the patient's level of education, experience in reading values of vital signs, or knowledge about his/her disease.
Actual usage	Healthcare professionals had experience with wired-based sensor platforms (i.e., Holter monitors, CGM) for remote monitoring of their chronically ill patients.	Participants confirmed not to have used a similar remote and continuous monitoring platform before.

The social influence aspects were closely related to healthcare professionals' behavioural intention, job relevance, perceived usefulness, and perceived ease of use. The findings from the first interview study also involved the actual usage aspects; however, in the second interview study, the healthcare professionals confirmed not to have a similar experience with a sensor-based platform for remote and continuous monitoring of their patients. Participants were considering the proposed SBNHealth prototype as an innovative solution for them and their healthcare institution.

The concerns of the healthcare professionals about the truth-telling aspects were very similar in both interview studies. They thought a patient's access to his/her vital signs may affect the medical condition, and cause stress or discomfort for the patient. Participants agreed that this situation might also depend on the patient's level of education, their experience in reading and understanding values of vital signs, or knowledge about the disease. Nevertheless, when reading values of the vital signs using the SBNHealth, the patient will have the normal range of every vital sign shown under the measured value. Hence, this will facilitate the reading and understanding of the patient's condition. If this is related to the findings of other studies, it can be concluded that patient's access to his/her data seemed to have helped them prepare for the visits with doctors (Rexhepi et al., 2016).

8.2.3 Conclusion

The process of within-method triangulation enabled a better overview and integration of the findings from both interview studies. Even though the aims and design of both studies were different, they relied on the same phenomenon. The first interview study aimed to investigate healthcare professionals' attitudes and perceptions on using sensor-based platforms (generally), while the second interview study focused on their views on a proposed sensor-based prototype.

The findings of the interview studies in this thesis, provided very similar results on the general aspects of sensor-based platforms, i.e., the ones that healthcare professionals had experience with and could provide opinions on. Although a lot of findings from the two research studies complement and confirm each other, there were further findings from the second interview study that provided a more complete picture of the application of sensor-based platforms for remote and continuous monitoring of patients in a developing country, Kosovo, as follows:

- HCPs discussed more practical aspects of incorporating the proposed sensor-based platform into their daily routines,
- the impact of the proposed sensor-based prototype on the prescription of patient's therapies was elaborated more in detail,
- the healthcare institutional approaches of using sensor-based platforms were analysed and compared (application on a private, or a public healthcare centre, or the impact on overall healthcare setting of Kosovo),
- the identified challenges added further value and important feedback to those mentioned in the first interview study,
- HCPs' proposals on the design and technical functionalities that they perceived as needed for remote and continuous monitoring of their patients.

Hence, the second interview study helped to get more detailed feedback and examples on the functional aspects of a sensor-based platform. This is considered expected as, in the second interview study, the participants first used the sensor-based prototype and after that, they were asked questions about the experience with the proposed SBNHealth prototype.

Similarly, in the discussion of the application of the sensor-based platforms based on technology acceptance constructs, the findings were generally overlapping and could be easily integrated as participants perceived the platform as useful, easy to use, intended to work with it as they perceived such platform would facilitate their work, have a job relevance, improve their performance, and provide an innovative solution for remote and real-time monitoring of their chronically ill patients (social influence).

8.3 Thesis findings related to the relevant literature

Emerging technologies, such as sensor-based platforms for remote and continuous patient monitoring enable improved outcomes and easily accessible healthcare services. Findings from the Spyglass Consulting Group (2019), based on a survey of 100 interviews with clinical informatics and health IT of the US-based healthcare provider organizations, showed that 88% of hospitals and health systems have planned to invest or invested in remote patient monitoring platforms for chronically ill patients. These results are promising towards the improvement of care and services delivered to patients. Hence, research related to healthcare professionals' attitudes and perceptions, and their evaluation of a sensor-based prototype as the one proposed in this thesis, provide further guidance on the plans towards integrating remote monitoring into healthcare settings for better treatment and management of chronic diseases. Even though the focus of this thesis was on a developing country, Kosovo, the findings of previous reports performed on developed countries as presented in Table 2.4, provide evidence and suggestions on the pathways to follow and challenges to consider more carefully for the low-and-middle-income countries.

While the focus was on a country within a developing region, this study aimed to investigate factors that have a direct impact on the challenges that countries in these regions face. Hence, the increased number of patients diagnosed with chronic diseases, and the limited resources to treat and manage them, remain serious tasks to focus on when considering the proposal of digital technologies to facilitate healthcare provision in these regions. In this context, the findings of this research project on the impact of the sensor-based platforms on the number of visits for chronically ill patients showed that there will be fewer clinical visits when patients are using sensor-based remote and continuous monitoring platforms. This advantage was considered as a prerequisite in the report of VivaLNK (2019) performed with more than 100 patients over 40 years old in US. They found that 64% of participants confirmed that they would put on a sensor-based wearable device if it reduced their number of clinical visits. The reduced number of clinical visits was discussed in this thesis by the HCPs in the second interview study[9] as very important especially in pandemic situations, such as one of Covid-19. In this regard, various investigations (Spyglass, 2021;

[9] This interview study was conducted in December 2020 - February 2021, during Covid-19 pandemic situation.

VivaLNK, 2021) reported the use of remote patient monitoring platforms to help enhance the patient-medical staff communication and, in this way, reduce the need to physically see each other. Nevertheless, besides the reduced number of clinical visits, Oikonomidi et al., (2021) in their recent study with 1010 adults with diabetes from 30 countries (with the majority of participants located in Canada (212), France (360), USA (138), UK (108), South Africa (18), Ireland (82), New Zealand (31)), concluded that 65% of participants reported adopting remote monitoring digital platforms if they will offer health improvements, help them monitor their food, and offer real-time feedback from a medical professional.

VivaLNK (2021) presented an investigation performed with hospitals and clinics which revealed a significant growth and improvement of remote patient monitoring platforms during the pandemic Covid-19 situation. Furthermore, the pandemic situation was considered an accelerator to the growing adoption and future plans for remote monitoring platforms. Nevertheless, as noted also in the VivaLNK report, there are still cost-related challenges that need addressing. Similar challenges were also identified from the findings of this research project. Hence, as suggested in this thesis, there should be a schema of financial support for the healthcare professionals who will provide remote monitoring and private healthcare institutions that would be affected by the reduced number of clinical visits. Even the health providers surveyed in Spyglass (2019) that were planning to expand their remote monitoring strategies, or those that started to invest, were facing challenges of limited budget and resources.

Besides the financial challenges, there are also data integration problems that should be considered carefully. During the interview studies of this thesis, some HCPs suggested integrating the proposed sensor-based prototype with existing clinical monitoring and information systems and workflow. This was also identified as a challenge that providers in Spyglass (2019) reported. According to those participants, the remote monitoring tools and data were not well integrated with the existing systems, for example, the clinical information system and inside the hospital monitoring system. Similarly, Viderman et al., (2022) proposed that a digital solution should fulfil some key characteristics that have to do with the performance, data safety, medical and financial outcomes due to its usage, and acceptance of the platform by the users (i.e., patients, healthcare professionals or caretakers).

The evaluation phase of the proposed sensor-based prototype revealed also some challenges related to clinical and managerial competencies. Hence, as the findings suggested, there should be a managerial will from the healthcare institutions to use and provide a remote monitoring platform to their chronically ill patients, and doctors and patients should arrange a communication channel, or a flow, to understand each other and work together for better monitoring. Similar suggestions were provided by Hilty et. al. (2021) in their scoping review, in which they also pointed out that collaboration between users was very much needed, and also institutional expertise needs to be evaluated and specified in detail to ensure the quality of care and successful implementation of remote patient monitoring using sensors.

Gagnon et. al. (2012) reviewed the existing literature data of 101 studies related to the adaptation process of digital technology and concluded that the process of adaptation of information technology was complex and may be influenced by different individual and organizational factors. This was found also in the two interview studies conducted in this thesis. However, training was suggested as a tool to facilitate the adaptation process. Similarly, Hilty et. al (2020) concluded that training and competency resources for sensor-based platforms and remote monitoring applications are needed, and especially the clinical skills to use these technologies. Nevertheless, most of the participants from the evaluation phase of the proposed SBNHealth, confirmed that the usage of the system was very easy. It is important to mention that these participants were of different backgrounds and ages, hence the usability and acceptability were not influenced by the age of the healthcare professionals, education level, or their experience. This was concluded also in the study by Denga, Moa, and Liuba (2014).

Several studies, and also this thesis's findings, reported cost reduction in the treatment and management of chronic diseases from the patient's side if they were using sensor-based platforms for remote and continuous monitoring of their chronic condition. In their review, Cruz, Brooks, and Marques (2014) confirmed that remote patient monitoring platforms are cheaper than clinical ones. Similarly, the participants of the empirical studies performed in this thesis, talking generally about the sensor-based platforms, pointed out that at the beginning, when buying the sensor-based device, it may be costly to patients, however, in the long term, it will serve them in reducing the overall costs, considering the reduced number of clinical visits, remote communication and consultation with their medical staff, continuous monitoring, and reduced traveling time and related expenses. Stanhope et. al. (2016) through their concurrent matched cohort study conducted in the US, compared costs and inpatient visitations for patients with cardiovascular diseases, who received telemonitoring and those who did not. Hence, they estimated a reduced inpatient visitation rate of 4.9% and a reduction in the overall medical costs of $13,608 over 24 months. Viderman (2022) concluded that sensor-based platforms may be considered to reduce the cost of hospitalization, hospital stay and bed turnover.

The proposed SBNHealth prototype offered HCPs the possibility to continuously monitor and get patients' vital signs in real-time (subsection 6.7.2.5). This functionality was evaluated as helpful for a specific group of patients, as receiving real-time data would be time-consuming for medical staff to monitor and evaluate all of a patient's information. Furthermore, one participant even declared that when at home, the patient does not need to transmit data all the time, in case he/she needs to do it, then the patient should be hospitalized. This was not the case with the findings reported by VivaLNK (2021), in which around 90% of the participants thought that continuous, 24-hour data, were more important than periodic information (i.e., every two hours or based on patient willingness as offered by the SBNHealth). Similarly, Verrillo et al. (2019) reported a 27% decrease in the rate of complications of health conditions for the continuous vital sign monitored patients and a significant decrease in the number of cases of patients that were transferred to an intensive care unit.

The HCPs found the visualization of vital signs in the SBNHealth as very useful and easy to access, the grouping of information as appropriate and not complicated to follow, and the presentation of the values of vital signs very understandable as they could see all five vital signs (heart rate, oxygen saturation, systolic and diastolic blood pressure, and respiratory rate) either in tabular or graphical form. However, participants suggested having additional patient information shown in the SBNHealth web portal, for example, gender; or other parameters that would be useful for them such as temperature. These are considered important suggestions for further improvement of the proposed sensor-based prototype. Similar information was shown on the patient monitoring prototype proposed by Hameed, Mohamad, Hamid, and Ţapus (2016). Nevertheless, the monitoring staff, in their proposed prototype, could see the values of only one parameter at a time, for example, a table with temperature values for every measurement, or they needed to open another web page to see the blood pressure table with values. Hence, for the medical staff, this can be time-consuming and complicated to compare the parameters one by one.

Truth-telling in healthcare settings was elaborated as an emerging variable from the findings of the first interview study conducted with HCPs as part of this thesis. Hence, participants raised the discussion that a patient's access to his/her vital signs may cause stress, discomfort and even affect the patient's medical condition. Similar feedback was also given during the second interview study; however, in this case, HCPs were more detailed in their opinions and added that truth-telling may affect some chronically ill patients that were not well educated or informed about their disease, or cannot read the values of the vital signs properly. Hence, the transmission of education and advice may be needed on an ongoing basis to some patients, for example, while using sensor-based prototypes they will have direct access to their vital signs. As Wakefield et. al. (2011) also concluded, engaging patients and providing them with information on their disease with close monitoring of medical staff, can improve healthcare outcomes in chronically ill patients while using remote monitoring platforms.

The proposed SBNHealth prototype enabled a simple mobile application that was supposed to be used by a chronically ill patient. The patient could perform measurements of vital signs using this application, share the vital signs with the monitoring staff, generate reports of measurements within a specific interval of time and access the values of the vital signs (subsection 6.7.1). Hence, during the evaluation phase of the proposed sensor-based prototype, healthcare professionals were asked how this might affect a patient's life, their wellbeing, and their medical condition. The findings showed a diversity of opinions which may depend on a patient's education and knowledge about his/her disease, as discussed above. However, there were also opinions that patients might feel happier, more comfortable, informed about their medical condition, and safer knowing that medical staff was monitoring them using the proposed SBNHealth platform. Similar findings were reported also by Grant, Rockwood, and Stennes (2015) when evaluating user satisfaction with remote monitoring services offered by 14 home healthcare agencies in five different US countries. The findings of this study showed that users of remote monitoring were happy and satisfied with the received home healthcare services after being discharged from the hospital. Additionally, in the survey conducted by VivaLNK (2019), 55% of the surveyed patients said they would use a wearable health monitoring device at home.

Muigg et. al. (2019) while evaluating telehealth readiness in diabetes care, through an online survey with Austrian practitioners found that participants perceived these platforms to enhance the quality of healthcare services and treatment provided, to have a better impact on the medical therapies that they were receiving, reduce traveling time and waiting time for doctor appointments. While this study also identified some other barriers related to reduced physical communication between the patient and medical staff, healthcare professionals' time and financial support to provide telehealth advice, as well as data and security issues. Similarly, HCPs surveyed in the interview studies as part of this thesis, provided the same benefits, however, they did not consider as a time-consuming process the remote patient monitoring using the proposed SBNHealth prototype. Moreover, they were describing how they could allocate time during their working schedule to view remote patients' vital signs and provide feedback to those who were in a more critical situation.

The overall findings of this thesis present a strong ground for informing the system designers, providers, and care managers about HCPs' attitudes, perceptions, opinions, and suggestions for a remote and continuous patient monitoring architecture based on sensors, for chronically ill patients. The proposed SBNHealth prototype and the tasks performed with it during the evaluation phase of this thesis can be considered as a building block and a starting point towards engagement strategies and involvement of care managers in the development process of sensor-based platforms for remote patient monitoring. A similar strategy was reported also from the Spyglass (2019) survey, in which 89% of the providers who participated in this study, confirmed to be in the process of developing or had started with the engagement strategies to involve and encourage HCP, patients, family members, and caregivers. Further to this, several studies (Gargon et al., 2019; Marcolino et al., 2019; Solino-Fernandez et al., 2019) identified the need to develop methodologies, implement and evaluate (either quantitatively or qualitatively) health-related platforms for remote monitoring or clinical and competency-based interventions. Hence, in this regard, the findings of both qualitative studies within this thesis present important consideration of medical staff attitudes as part of the design and proposal of a sensor-based architecture, and later the implementation and evaluation of the proposed SBNHealth prototype. Consequently, the trustworthiness of this research study is discussed in detail in the next section.

8.4 Trustworthiness of the research

Research trustworthiness presents an important measure of a study's quality of research, evaluated in terms of how well the formulated research questions were answered and on the overall quality of the research that was carried out (section 3.4). Hence, research trustworthiness in a qualitative study, in terms of credibility, transferability, dependability, and confirmability, will further enforce the research findings (Lincoln & Guba, 1985).

As presented in section 8.2, within method triangulation was used to integrate and evaluate the findings of both interview studies conducted in this research study. Hence, the aim of the within method triangulation was to evaluate the consistency, trustworthiness, and quality of this research project, as proposed also by Golafshani (2003). Therefore, the process of within method triangulation discussed in detail the key points where most of the constructs from both interview studies provided very similar results and, in this way, according to Denzin (1978), this confirms that the findings can be considered as consistent, credible, and reliable, which ensures this research study to have confidence in the results it generated.

To further discuss the trustworthiness of this research study, the four key factors using the techniques proposed by Lincoln and Guba (1985), are elaborated as follows:

- Credibility

Some of the techniques to ensure the credibility of a research study suggest the engagement of the researcher in the research setting, to better understand the environment and related factors that may have an impact on the study's findings. Hence, the researcher [AB] conducted both interview studies in the hospital setting during the working schedule of the participants. This means that there was a continuous engagement with the setting, an observation of the work performed there, the sensor-based platforms that were used, and the routine of the tasks that the participants performed. Furthermore, this process lasted on a monthly basis, starting from the ethical approval process until the end of the interviewing process, for both qualitative studies.

- Transferability

  This thesis tried to elaborate in detail and describe thoroughly the investigated phenomenon, and present the research results in a manner that is possible for other readers to follow them easily and validate the extent to which the design of the studies conducted, the research instrument, or the findings generated, would be valid for other settings (i.e., other private clinics in Kosovo, or other healthcare institutions in developing countries) or people (i.e., investigating the acceptance of chronically ill patients, or managerial people of the healthcare institutions).

- Dependability

  External researchers, in this case, reviewers, can be mentioned as people that provided positive evaluation about the research process and the research findings that emerged from both interview studies, throughout the reviewing process of the papers submitted to various conferences and journals (listed on page 17). In this way, the findings of this thesis were in a form examined and evaluated so that the results and the drawn conclusions were supported by the gathered field data.

- Confirmability

  To ensure the confirmability of this research, the findings of both interview studies were compared and elaborated in detail in section 8.2 using within-method triangulation.

Besides the above techniques suggested by Lincoln and Guba (1985), and the within method triangulation, a 'thick' description strategy was used to provide the original citations of the participant's words during the interviewing process. As presented in chapter 5 and chapter 7, while elaborating the results of every theme/sub-theme, direct quotations were included to illustrate the original views of the HCPs, their expressions, perceptions, and reactions towards the investigated phenomena, and thus to increase this research quality and trustworthiness of the findings, as suggested by Patton (2002).

This thesis successfully identified various aspects of healthcare professionals' intentions to use a sensor-based platform for remote and continuous monitoring of their patients. Nevertheless, some limitations could be addressed with future studies. Hence, the following section presents the strengths and limitations of this thesis.

8.5 Strengths and limitations

This section presents the strengths and limitations of the research presented in this thesis. The specific details on the strengths and limitations of the individual interview studies can be found in their respective chapters, more specifically, in sections 5.7 and 7.7. Moreover, section 6.8 presents the limitations of the proposed SBNHealth prototype.

The benefits of conducting two qualitative studies for this research are closely related to the presentation of the complete picture of the proposal and usage of a sensor-based prototype for remote and continuous monitoring of chronically ill patients in a SEE developing country, Kosovo. Hence, some research questions could not be answered from the first interview study, as participants did not have experience with real-time and distance-based monitoring platforms. Therefore, after proposing the sensor-based architecture and implementing the SBNHealth prototype, more thorough and detailed feedback, was possible, and this helped to further explain the findings of the first interview study and conclude on the investigated phenomena. Further to this, the qualitative studies included participants from different healthcare disciplines that were treating patients with chronic conditions. Hence, this helped to identify other clinical areas where sensor-based platforms could be applied to provide better healthcare services and improve patient care.

The research performed in this thesis consisted of two small-scale interview studies with healthcare professionals, from just one practice of implementation. As described in section 4.3, the initial plan was to perform the research studies in the public healthcare centre of Kosovo, the UCCK; however, due to ethical approval restrictions, this was not possible. As such, another private healthcare centre in Prishtina was selected, as the biggest private institution there and one that was likely to treat chronically ill patients. The interviews with nurses in the first interview study were arranged by the administrative nurse of the American Hospital in Kosovo, based on their availability and willingness to participate in the research. The second interview study included the same participants that provided opinions during the first investigation, who were still working in the same hospital. Hence, the actual sample may be self-selecting by including participants who were more likely to be interested in, and therefore positive towards, technology. This had an impact also on the number of interviews which, for the first interview study, was 26. Further to this, this sample may well not be representative of healthcare professionals of Kosovo, since the study consisted of just one practice of implementation, even though the interview studies were conducted in Prishtina, the capital city, and in the largest private hospital, where 23% of participants confirmed to work in the private and public hospital (UCCK) at the same time. This may affect the generalizability of the findings of this thesis, even though they provide a thorough investigation of HCPs' adoption and usage of sensor-based platforms, and factors associated with it. Nonetheless, considering the detailed design, and methods, it would be possible to perform similar studies in other settings and include more participants, in a future study as recommended in section 9.5. In this case, the ethical procedures should be followed similarly as described in section 4.3, and the same interview guides could be used to perform research studies with other healthcare professionals working in different healthcare institutions across Kosovo, or even in other developing countries that have similar characteristics.

The purpose of this study was to investigate the needs, attitudes, adoption, and possible implementation of sensor-based platforms in a SEE developing country, i.e., Kosovo. Hence, given the detailed analysis and research process, the healthcare professionals' positive attitudes, and the thorough discussion, it is possible that the findings of this thesis might be applicable, or transferable, to other healthcare settings in developing countries, with similar characteristics to Kosovo, e.g., other countries in SE Europe.

Another limitation of this study was that the healthcare professionals did not have any experience with real-time and distance-based monitoring of chronically ill patients. They were using some forms of digital monitoring systems (section 4.4); however, no real-time and continuous monitoring for longer periods of time was not possible using them. Nevertheless, also while using the SBNHealth there were only a few minutes of their time that they could allocate for it. Hence, the tasks that they performed with the proposed SBNHealth prototype during the second interview study, lasted around 14 minutes, considering that the interviews for both research studies were conducted within the hospital premises and during healthcare professionals' working schedules. Hence, participants had limited time to perform the tasks and answer the interview questions, as they had patients waiting for them. This could be overcome with a secure access connection to the SBNHealth system for a longer interval (i.e., a URL where HCPs could create their accounts and login, whenever they have time, within a trial period of 1-2 months) and enabling the healthcare professionals to try out the system functionalities. After this experience, an interview study might be further enriched with findings and recommendations based on this practice and their experiences.

Further to this, the researcher [AB] played the role of the patient. Hence, the study did not have real chronically ill patients involved, as the aim was to investigate and evaluate the HCPs' points of view, and their acceptance of SBN for remote and continuous monitoring. Hence, a future qualitative study including real chronic patients could be considered to address this limitation (section 9.5). This could be easily achieved; however, the only requirement would be for the patient to have a smartphone that has heart rate sensors built in. As such, the proposed SBNHealth Android application could be installed, and the patient could record his/her vital signs and share them afterward with the healthcare professionals. This scenario would enable the study to get more values, data, information, and could also investigate patients' attitudes and perceptions on remote and continuous monitoring.

The methodological process of this thesis consisting of only qualitative research has also its limitations. Hence, a quantitative approach could have provided more extensive analyses, coupled results, and numeric values on the investigation of healthcare professionals' acceptance and their evaluation of the proposed sensor-based prototype. Hence, having the SBNHealth prototype used by the participants in a trial period, a future research study could consist of a questionnaire that would collect participants' information on the usability, ethical, practical, and administrative aspects of using remote and continuous monitoring based on sensor platforms.

Despite the limitations mentioned above, which are further discussed and suggestions for addressing them are proposed in section 9.5, the findings of this thesis present novel results for SEE developing countries and Kosovo, towards healthcare professionals' adoption and successful implementation of sensor-based platforms.

8.6 Conclusion

This chapter presented a detailed discussion on the integration through the within method triangulation, of the findings generated from both interview studies. Hence, it can be concluded that the results of both interview studies provided similar results on the general aspects of sensor-based platforms. Nonetheless, the constructs and findings provided in the second interview study were more detailed and analysed with real examples, as participants had the chance to perform tasks with the proposed sensor-based prototype.

From the detailed discussion of the findings of this thesis with those of the similar literature, is it concluded that remote monitoring technologies gained significant attention and applicability especially during the last years, and in this pandemic situation with Covid-19. This was also mentioned by the participants of the second interview study, which was conducted in that period of time. Therefore, the findings of this thesis on the healthcare professionals' attitudes and perceptions on the application of sensor-based platforms, and their evaluation on a proposed SBNHealth prototype, present a strong base for involving users in the design and development process, and for engaging them with such platforms at their early stage of application.

Detailed conclusions on the findings of this thesis and recommendations for policy and practice and future work are presented in the next chapter 9.

Chapter 9 Conclusions

9.1 Introduction

The previous chapters provided detailed information on the work performed throughout this thesis on the two empirical studies, and the proposal of the sensor-based prototype. Furthermore, the integration of results of both interview studies was discussed using the triangulation process. This chapter will provide a summary of the whole thesis, results, and its contribution to the sensor-based research area.

Hence, this chapter aims to synthesize the research performed as a whole and conclude this thesis's findings in relation to the predefined aims and objectives as presented in section 9.2. The contribution of this thesis to new knowledge, considering the impact and benefits for the end-users and healthcare institutions, is presented in section 9.3. The technology acceptance and managerial aspects that have an implication for practice and policy are elaborated in detail in section 9.4. Suggestions for future research are proposed in section 9.5. Finally, section 9.6 concludes this thesis.

9.2 Summary of thesis

The review of the literature, the results of both empirical studies, and the proposal of the sensor-based platform, summarize the work conducted to address the predefined aims and objectives as presented in section 1.5, and to answer the research questions as presented in subsection 2.8.3. Hence, this section presents a synthesis of this thesis findings to address and answer emerging research outcomes.

First, the outcomes of the aims and objectives are discussed in subsections 9.2.1 and 9.2.2, and after that, the overall outcomes of all the research questions are addressed in subsection 9.2.3, as follows.

9.2.1 Aims outcomes

Considering the findings of both interview studies (chapters 5 and 7) and the design, proposal, and implementation details (chapter 6) of the sensor-based prototype, it is concluded that this research managed to fulfil its aims. Hence, the following paragraphs will elaborate on the predefined aims of this thesis and how they were fulfilled.

The overall aim of this thesis was:

(1) to understand the needs and acceptance of sensor-based platforms in a developing country, i.e., Kosovo, and based on that to propose a remote and continuous monitoring application for chronically ill patients.

The findings of the first interview study with HCPs presented their attitudes, perceptions, and concerns on the application of remote and continuous sensor-based platforms for monitoring their chronically ill patients. Based on these findings, this thesis proposed a sensor-based prototype, which aimed to consider existing health practices and provide the information that HCPs needed for remote monitoring of their patients.

The second aim of this thesis was:

(2) to provide recommendations and guidance for system designers from the healthcare professionals' point of view, regarding the functionalities that they perceived as being useful and needed to monitor patients with a chronic illness at a distance.

The healthcare professionals that participated in both interview studies had no prior experience in remote and continuous monitoring of their patient's vital signs. Hence, both interview studies were designed based on technology acceptance theories to understand users' needs. Aiming to get a wider view of HCPs' attitudes and perceptions, various technology acceptance variables were combined. Therefore, the findings of both interview studies provided various recommendations, guidance, health practices, and existing workflows, so that system designers could implement a digital product that will facilitate HCPs' work considering their needs and current practices, and overall improve patient care (as presented in section 6.2).

To fulfil the aims of this thesis, a set of research outcomes was predefined. Hence, the next subsection presents a summary of this thesis findings in relation to the outcomes defined at the beginning of this research study.

9.2.2 Objectives outcomes

There were six research outcomes predefined to fulfil the aims of this thesis, as presented below:

(1) To analyse the current application and use of remote monitoring technologies, and following this, elaborate the benefits and impact of having real-time and distance-based monitoring of vital signs using sensor-based platforms;
(2) To review the existing user acceptance models and identify prominent models that may be used to understand healthcare professionals' acceptance and adoption of sensor-based platforms for remote and continuous monitoring of chronically ill patients;
(3) To identify the current needs, existing practices that healthcare professionals have, and the key vital signs they need, to monitor chronically ill patients at a distance;
(4) To propose a feasible and cost-effective sensor-based platform that enables remote and continuous monitoring of chronically ill patients;
(5) To empirically evaluate the proposed sensor-based platform based on feedback from healthcare professionals;
(6) To provide model guidance for system designers from the healthcare professionals' point of view.

All of these objectives were successfully addressed and elaborated in detail through the chapters of this thesis. Hence, as presented in chapter 2, a thorough review and critical analysis of similar approaches, helped to identify the key findings, emerging issues, and existing gaps. The review of sensor-based approaches and the user acceptance methodologies, as presented in Table 2.4 and Table 2.5, provided more details on the benefits, impacts, limitations, and future works on the existing platforms, and technology acceptance models (Objectives 1 and 2).

The emerging issues and the identified gaps in chapter 2, helped in defining the research questions and the methods to address them. Therefore, the interview guide of the first interview study (chapter 5) was formulated to answer the research questions by identifying the needs, existing workflows, practices, vital signs, presentation methods, impacts, challenges, and possible drawbacks of using sensor-based platforms for remote and continuous monitoring of chronically ill patients (Objectives 3, 4, and 6). Further to this, the findings of the first interview study presented the base ground for proposing, designing, and implementing a sensor-based prototype (chapter 6) to suit the identified needs of a developing country, Kosovo (Objectives 4 and 6). The proposed sensor-based prototype was given to the same group of healthcare professionals to perform tasks with it (chapter 7), and get their feedback as part of the evaluation process for this thesis (Objectives 5 and 6).

9.2.3 Research questions outcome

The design and implementation of the SBNHealth prototype (chapter 6), and the findings of both empirical studies (chapter 5 and 7) provided the research base for addressing and answering the questions as presented in subsection 2.8.3. The following paragraphs will provide detailed information and answers for each of them.

Research question 1:

> In what context, will the application of sensor-based platforms help developing countries, in this study Kosovo, to treat and manage chronic diseases?

This research question was addressed in subsection 7.5.5.7. However, before that, the first interview study (chapter 5) provided information on the profile of the chronically ill patients in Kosovo (subsection 5.5.5), the vital signs that need continuous monitoring for chronic diseases (subsection 5.5.6), and the readiness to provide remote monitoring through sensor-based platforms (subsection 5.5.7). Hence, the findings of the empirical studies presented several aspects such as improved patient care, better diagnosis, remote and continuous monitoring, distance-based communication, better overview of the patient's clinical situation, cost savings, few hospital visits (which was considered very beneficial especially in pandemic situations), lower the number of hospitalization days, and facilitate the work of HCPs.

Research question 2:

> How can the application of sensor-based platforms address the needs of healthcare centres in a developing country (i.e., Kosovo)?

As the findings of this study showed, remote and continuous monitoring through sensor-based platforms would affect the healthcare sector of Kosovo, clinical decision making, number of hospital visits, and hospitalization days. For more details, this research question is elaborated in different perspectives in subsection 5.5.8 (more specifically, 5.5.8.1, 5.5.8.2, 5.5.8.4, and 5.5.8.5), and subsection 7.5.3, following HCPs experience and tasks with the proposed SBNHealth prototype.

Research question 3:

> What may be the factors leading to the successful application of sensor-based platforms?

This research question is addressed in subsection 7.5.5. Hence, its suitability for the healthcare setting, impact on clinical decision making, effectiveness on patient care and patient life, reduced costs related to chronic diseases, and the positive attitude and impact on the healthcare sector of a developing country, present some of the factors elaborated in this section, that may lead to a successful implementation of sensor-based platforms.

Research question 4:

> What may be the factors that may challenge the implementation of SBN in the health system of a developing country?

Both interview studies elaborated challenges for the successful implementation and application of sensor-based platforms in the healthcare setting of Kosovo and found factors such as the cost of the proposed sensor-based platform, lack of health insurance, patient and doctor cooperation, accuracy of the values of the vital signs measured by the SBN, managerial will from the healthcare institutions to use and provide a remote monitoring platform to their chronically ill patients, payment policy for the medical staff who will provide remote and continuous monitoring, and responsible medical staff for monitoring patients at a distance. Hence, this research question is addressed in subsections 5.5.8.8 and 7.5.6.

Research question 5:

> How do healthcare professionals consider the application of sensor-based networks will affect healthcare costs?

The impact of the sensor-based platforms on the financial aspect of a chronically ill patient was elaborated in subsections 5.5.8.4 and 7.5.5.5. Both these sections considered views of HCPs regarding the number of hospital visits, hospitalization days, traveling expenses, and medication costs, to have a direct impact on the overall financial aspect of treating and managing chronic diseases. Nevertheless, there is a need for future research to provide numeric values from a detailed cost analysis on the healthcare costs of a chronically-ill patient utilising a sensor-based platform, compared with another patient that uses traditional methods (section 9.5).

Research question 6:

What should be the characteristics of an efficient sensor-based framework for healthcare in developing countries?

Considering the needs of a developing country, i.e., Kosovo, the sensor-based platform should provide an accurate, feasible, and cost-effective solution towards the increasing number of chronically ill patients, and the limited resources to treat and manage them. From the technical perspective, the platform should be easy to use, perform the functionalities that the HCPs need to remotely and continuously monitor their patients, and consider the actual health practices, for easier integration with the existing workflows and systems. Further information addressing this research question is summarized in section 6.2 (following detailed elaboration in subsections 5.5.7.3, 5.5.7.4, and 5.5.8.6) and subsections 7.5.7 - 7.5.12 contain characteristics from the technical point of view for system designers.

9.3 Contribution to new knowledge

The research conducted in this thesis presents the first study of its kind in a developing country in SEE, and Kosovo, as indicated also in the literature review (chapter 2). This study is built up on technology acceptance constructs, which were combined and led to the foundation of the research methods used for both investigation studies (chapter 5 and chapter 7). As such, the interview guides used in both interview studies contained questions that investigated specific aspects of user acceptance, such as perceived usefulness, perceived ease-of-use, job relevance, performance expectations, social influence, output quality, actual usage, performance expectancy, job relevance, and social influence. Hence, the combination of various technology acceptance variables from different models enabled the investigation of different aspects related to the application of digital technology (i.e., in this study, sensor-based platforms) into the healthcare settings. In this context, truth-telling emerged as a new technology acceptance construct from the findings of this study, which also represents a novel scientific contribution.

In this way, the proposal, implementation, and evaluation of the sensor-based prototype present a contribution that this thesis provides to the healthcare settings of Kosovo, as an example of a developing country. The healthcare professionals, as participants of both empirical studies conducted in this thesis, had no prior experience in remote and continuous monitoring of their chronically ill patients, thus by using the proposed sensor-based prototype they got an idea of this type of monitoring and possibilities it may offer to them and their patients. This enabled empirical evaluation, field studies, and findings that contributed to the sensor-based research area (as shown in the List of publications, page xvii), as well as recommendations and suggestions for system implementers, considering that no such studies had previously been undertaken (section 2.8).

Hence, this thesis presents the following important contributions to new knowledge as:

- a research study based on technology acceptance variables, on the adoption and acceptance of sensor-based platforms for remote and continuous monitoring of chronically ill patients, in a developing country in SEE, i.e., Kosovo, which contributed to the research area with unique results,

- a proposal for a feasible sensor-based prototype based on healthcare professionals' opinions, feedback, and current work practices, which was derived from scientific results of the research studies (chapter 5 and 7), and
- an empirical evaluation of the proposed sensor-based prototype, to provide recommendations and future suggestions for research and for system designers from the healthcare professionals' point of view.

While doing this study in Kosovo, several details may be useful to other developing countries that have similar characteristics. Therefore, the findings of this thesis may be transferrable to other developing countries. Nevertheless, the perceptions, needs, and attitudes of healthcare professionals in other developing countries may be different from those of Kosovo, presented in this thesis. There may be other clinical practices applied, cultural differences on acceptance of sensor-based platforms, or other factors, that may be investigated in a future study, as is proposed in section 9.5.

This thesis presents some interesting and novel findings which differ from, and add to, those presented in the literature review (chapter 2). Hence, this thesis makes an important contribution to knowledge regarding the practices of healthcare professionals and the patient care they provide, and this is elaborated in subsection 9.3.1, while the detailed benefits for end-users and healthcare institutions are presented in subsection 9.3.2.

9.3.1 Implications on healthcare professionals' practices and patient care

This thesis contributes to new knowledge through various perspectives of the implication of sensor-based platforms on healthcare professionals' current work practices and healthcare provision, affecting also patient care. Regarding the implications for healthcare professionals' work, both research studies (chapter 5 and 7) revealed the following contributions regarding continuous and remote monitoring of chronically ill patients, using sensor-based platforms:

- more accurate therapies considering that now healthcare professionals have a detailed report on a patient's vital signs over a longer period of time;
- remote prescription/changes to therapies for chronically ill patients that are monitored continuously and the healthcare professionals know their pathology, anamnesis, and have a detailed overview of their condition. However, this does not apply to those who use venous therapy or those in a critical condition and with fluctuating values of vital signs;
- considering the functionalities that the proposed sensor-based prototype offered to healthcare professionals, they confirmed that it will not take a lot of their time or overload them. Furthermore, participants proposed to allocate a separate time slot to monitor chronically ill patients at a distance, during their daily shifts;
- the real-time monitoring would apply only to a specific group of patients, as receiving real-time data would be more time consuming for healthcare professionals to monitor and evaluate all of this information;
- their current work practices were considered and the proposed sensor-based platform offered similar functionalities that healthcare professionals were used to, i.e., monitoring interval for

chronically ill patients (every 2 hours, or continuously), presentation of the values of vital signs using tables or graphs, patient information, and similar.

The implications of the sensor-based platforms for patient care were considered to be:

- improved patient care by remote and continuous monitoring, which provides a detailed overview of a patient's medical condition, and enables communication at a distance with the monitoring personnel;
- reduced number of physical visits to medical centres, which has an impact on saving a patient's time, traveling expenses, unnecessary phone calls, and reduces costs associated with these processes;
- reduced hospitalization days for patients who are hospitalized just for monitoring their vital signs, but for the other group of critical patients that need hospitalization and clinical surveillance, this may not be appropriate;
- affecting a patient's life in two different aspects: by causing stress to those who have little information about their disease, or no experience in reading the values of the vital signs; and by providing information on medical condition over a longer interval of time, for those who want to monitor themselves continuously. The latter was considered very helpful, especially in pandemic situations such as Covid-19, i.e., to avoid frequent visits to medical centres for minor consultations or not being able to have a consultation at all.

This thesis investigated healthcare professionals' opinions and perceptions about sensor-based platforms. However, as the findings in subsection 5.5.8.3 showed, medical staff have a direct role in proposing, implementing, and using sensor-based platforms, considering that patients may get information about remote monitoring platforms by them. Further to this, as this thesis found, healthcare professionals can support patients to adapt sensor-based platforms easily. Considering the individual aspect, either from the healthcare professionals' point of view or the patient's quality of life, the application of sensor-based platforms has an impact also in the healthcare centres and on the healthcare system of a developing country. Therefore, the following subsection provides more details in these two contexts.

9.3.2 Benefits for healthcare centres and healthcare system of a developing country

Considering the challenges that the healthcare system of Kosovo, as a developing country, and the healthcare centres there are facing with the increasing number of patients diagnosed with chronic diseases, and their limited capacities to offer better healthcare services (chapter 1 and 2), the application of sensor-based platforms seemed to help in various contexts are presented in the following.

The benefits of implementing sensor-based platforms for the healthcare centres were mentioned to be related to the following aspects:

- provide improved healthcare services by offering remote monitoring, and having a detailed overview of a patient's condition which is closely related to more accurate therapies, better monitoring, and continuous communication;
- implement an innovative solution considering that no such platforms are available in Kosovo, or even in other SEE developing countries;

- offer advanced healthcare services to provide more detailed monitoring considering the positive attitudes of the healthcare professionals and their willingness to allocate time-slots within their daily shifts to provide remote monitoring to their chronically ill patients.

The implications of sensor-based platforms, either in the individual context, as presented in the previous subsection, or at the institutional level, both affect the overall healthcare system of a developing country by:

- reducing the number of patients into medical centres;
- lowering medical expenses for treating and managing chronic diseases;
- improving patient care by monitoring them remotely, as this may make the patient feel happier, more comfortable, informed about his/her medical condition, and safer knowing that medical staff is monitoring him/her using the sensor-based platform;
- increasing the effectiveness of care by reducing unnecessary clinical visits (especially during pandemic situations considering people's infections), and changing the institutional approach positively.

Consequently, all the factors mentioned above emerged from the findings of the empirical research conducted in this thesis, and present a contribution to new knowledge considering that no prior, similar, studies have been performed in Kosovo, or in any other developing countries in SEE. The following section will provide more details on another two perspectives of implication for practice and policy, considering the technology acceptance and managerial aspects.

9.4 Implication for practice and policymaking

The findings presented in this thesis may be useful for digital system designers, healthcare providers, and policymakers that aim to propose and implement sensor-based platforms for remote and continuous monitoring within the healthcare setting of a developing country, Kosovo. Furthermore, they present the ground base for understanding users' perception before proposing a sensor-based platform which, as proposed in the literature review (chapter 2) and as presented through the thesis findings, is considered important to provide useful information.

Healthcare providers and policymakers should understand the benefits of remote monitoring and its contribution to the healthcare system of a developing country. Hence, the findings of this study may bridge the existing gaps on:

- the lack of previous studies that investigated users' acceptance and proposed sensor-based platforms for remote and continuous monitoring in a developing country, Kosovo; and
- enable the creation of policies on the application of sensor-based platforms with respect to healthcare professionals' proposals, feedback, and intentions.

The implication of technology acceptance is further elaborated in subsection 9.4.1 below. Subsection 9.4.2 presents an overview of the implication of the findings of this thesis on the managerial aspects.

9.4.1 Technology acceptance, practical aspects

This thesis found that understanding of technology acceptance before proposing a digital system, respectively a sensor-based platform, has many benefits as below:

- it allows system designers to understand users' perspectives, their concerns, attitudes, opinions, current working practices, and methodologies;
- it enables the proposal of a digital solution based on users' needs, which has a direct impact on their acceptance of the proposed system;
- it provides an easy-to-use system that the users already have an idea of its designation, and purpose;
- identify possible difficulties and provide measures to solve them, before having the final digital product implemented;
- design a user-friendly, easy-to-use, and useful digital system, in this case, a sensor-based platform, that will fulfil the needs of the users and facilitate their work.

As shown in this thesis, the healthcare professionals perceived the proposed SBNHealth as effortless to use, easy to understand, and simple to view their chronically-ill patient's vital signs and communicate with them. This had a direct impact on participants' attitudes to use the proposed sensor-based prototype (intention to use), and their perceptions that the usage of the proposed platform will not take a lot of their time (perceived ease of use), or cause overload (effort expectancy), but in contrary, help them monitor their patients also remotely (job relevance).

Another new important factor that emerged from the findings of this thesis, and which is important to consider while investigating technology acceptance in healthcare, was the truth-telling variable. By using the proposed sensor-based prototype in this thesis, the patient would have access to his/her values of vital signs. Therefore, in case a value may not be within the normal range of values, the patient will see that, and according to healthcare professionals, this may affect the patient's health status. Hence, the system designers should evaluate the functionalities that they implement and how they can affect the medical condition of a patient, and resolve possible conflicting situations.

9.4.2 Managerial and governmental aspects

The managerial aspects are considered important for the successful implementation of a sensor-based platform. As discussed also from the participants of the empirical studies, the clinical applicability, the organizational aspects of providing remote monitoring, and approval of sensor-based platforms for use in a healthcare setting, present some of the key aspects that have a direct impact on the application of sensor-based platforms.

Therefore, as the findings of this thesis showed, there should be a managerial will from the healthcare institutions to use and provide a remote monitoring platform for their chronically-ill patients. Furthermore, the management of the healthcare institution should organize the responsible staff to provide feedback and monitor patients at a distance. As participants of the empirical studies in this thesis proposed, the healthcare institution may arrange the working schedule of existing healthcare professionals (i.e., working with shifts), delegate this responsibility to family doctors, specialized nurses, younger doctors without academic obligation, or create new teams of medical personnel who will provide 24/7 assistance.

This thesis also discussed the governmental implication and their role in providing guidelines and policies on remote patient monitoring. Hence, as suggested through this study, there should be formulated specific laws, regulations, and procedures that will protect patient information and the healthcare professional who will provide feedback at a distance. A communication strategy should also be drafted by the Ministry of Health, to provide clear processes and steps on offering remote patient monitoring, and ensuring accurate communication and data sharing between the patient and the monitoring personnel.

Further to these, the policymakers need to provide a financial support strategy for the medical personnel that will offer distance-based and continuous monitoring to their patients. This was one of the main challenges discussed by the healthcare professionals in this research study.

9.5 Suggestions for future research

Although this thesis has provided information on sensor-based platforms, their acceptance, applicability, and implementation details in a developing country (Kosovo), there are still unanswered questions and issues that need further investigation. Hence, this section will discuss the ideas and future research based on the findings of this thesis.

The empirical studies in this thesis were conducted in a private clinic in Kosovo, which means that, for practical reasons, this thesis had a single setting for its research. Therefore, a future qualitative study to investigate healthcare professionals' attitudes, and adoption for using sensor-based platforms, by involving more settings, i.e., further healthcare centres across Kosovo or within other developing countries, would enrich further the findings presented in this thesis. The same methodology could be used, and more participants could be involved to understand the extent to which the findings from the study are transferable, and in this way address the limitations of this thesis (section 8.5). Similarly, a larger-scale quantitative study, could examine how generalisable the findings are to other healthcare settings, either in Kosovo, or in other developing countries. Further to this, this future research can help to identify different intentions, various working practices, and probably cultural differences if several developing countries will be involved.

Future research is also needed to investigate patients' readiness to wear sensor-based platforms and their attitudes towards remote and continuous monitoring. Hence, a further qualitative study, this time involving chronically ill patients may be helpful to understand their views and experiences with the proposed sensor-based prototype. Findings from this future study may be integrated and triangulated with those presented in this thesis, to broaden the knowledge and provide more information on the application of sensor-based platforms in developing countries.

This thesis has provided a preliminary cost analysis based on literature data. However, a future quantitative study could provide numeric values from a detailed cost analysis on the healthcare costs of chronically ill patients wearing a sensor-based platform, compared with others that use more traditional healthcare services.

Truth-telling emerged as a new technology acceptance variable from the findings of this thesis. Participants in this research study discussed the truth-telling aspect that should be investigated when performing technology acceptance studies in healthcare settings. Therefore, future research is needed to investigate the impact of this variable on the acceptance, adoption, and usage of sensor-based platforms, and, overall, on a patient's health status. This is considered important information also for system designers, as they need to consider among other factors (i.e., perceived usefulness, perceived ease-of-use, job relevance, etc) also the medical aspects of users, before proposing digital products for the healthcare context.

In this thesis, the evaluation of the proposed sensor-based prototype was carried out using a qualitative study with healthcare professionals that participated in the first round of interviews (chapter 5). Nevertheless, this evaluation study included a low number of participants, considering that most of the healthcare professionals from the first interview study were not working in the American Hospital of Kosovo by that time. Therefore, a wider quantitative study would provide a more detailed evaluation of the proposed sensor-based prototype. Hence, this future study may be planned to provide the healthcare professionals with more time to perform tasks with the proposed sensor-based prototype and, after that, to invite them to fill out a questionnaire and provide their feedback. The findings of this future study can be integrated with those of the qualitative study conducted in this thesis (chapter 7) and, in this way, they can present an in-depth investigation and evaluation of the proposed sensor-based prototype.

There are other future implementation suggestions also discussed in section 6.8. Hence, the proposed SBNHealth prototype needs improvements in providing more accurate information, integration of additional vital signs (i.e., blood glucose, pulse, ECG, and temperature), and the proposal and design of the mobile unit (i.e., a sensor-based device) that would incorporate physical sensors and provide the patient's data from there.

9.6 Conclusions

This chapter concludes the thesis by providing a summary of the contribution to new knowledge and implication of the findings presented here for practice and policy. The findings of this thesis on the users' acceptance and adoption of sensor-based platforms, and the implementation and evaluation of the sensor-based prototype, provide a novel research contribution for the SEE developing countries, and particularly for Kosovo. The issues, challenges, and participant suggestions that were identified regarding the sensor-based platforms' applicability for remote and continuous monitoring of chronically ill patients also present important information for system designers when aiming to propose such digital products for developing countries.

In this context, as the findings of this thesis have shown, besides the perceived usefulness, perceived ease-of-use, job relevance, subjective norm, behavioural intention, and effort expectancy, there is another aspect that needs consideration when proposing new technology for healthcare settings. Truth-telling emerged as an important variable that may help to predict users' acceptance and adoption of sensor-based platforms.

The findings of this thesis provide a detailed overview of the potential benefits of using sensor-based platforms to provide remote and continuous monitoring in different aspects. Hence, starting from the individual context, the findings considered the impact of the application of sensor-based platforms for healthcare professionals and patients, through to the institutional aspects of healthcare providers and policymakers. Therefore, the findings of this thesis can provide useful information for hospital managers on how to improve patient monitoring and provide more information on their medical condition and, in this way, to offer innovative solutions and stay in line with new technological advances. Policymakers at the institutional levels (i.e., the Ministry of Health of Kosovo) may find useful information in this study, and evidence to inform national standards for remote patient monitoring.

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*References with an asterisk (*) indicate that the references have been translated from Albanian

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Appendices

Caveat

Please accept apologies for the quality of some of the images included in the appendices for this thesis. Some of them were downloaded as .pdf files, or exported as images and then include in this document. Every effort has been made to provide readability. Furthermore, please consider that some of the forms used during the interviewing processes were translated in Albanian as the native language of the participants. Hence, here are included only the English versions of the documents which were approved by the Research Ethics Committee of the University of Sheffield and the American Hospital of Kosovo during the research ethics approval process.

Appendix A.1 Study 1, Ethics Application (no. 008335)

The University Of Sheffield.

Application 008335

Section A: Applicant details

Date application started:
Sat 9 April 2016 at 20:34

First name:
Adelina

Last name:
Basholli

Email:
abasholli1@sheffield.ac.uk

Programme name:
Information Studies

Module name:
Information Studies
Last updated:
23/09/2016

Department:
Information School

Applying as:
Postgraduate research

Research project title:
Wireless monitoring systems for enhancing national health services in developing regions

Has your research project undergone academic review, in accordance with the appropriate process?
No

Similar applications:
- not entered -

Section B: Basic information

Supervisor

Name	Email
Peter Bath	p.a.bath@sheffield.ac.uk

Proposed project duration

Start date (of data collection):
Fri 1 July 2016

Anticipated end date (of project)
Sat 1 July 2017

3: Project code (where applicable)

Project externally funded?
- not entered -

Project code
- not entered -

Suitability

Takes place outside UK? Yes

Involves NHS? No

Health and/or social care human-interventional study? No

ESRC funded? No

Likely to lead to publication in a peer-reviewed journal? Yes

Led by another UK institution? No

Involves human tissue? No

Clinical trial or a medical device study? No

Involves social care services provided by a local authority? No

Involves adults who lack the capacity to consent? No

Involves research on groups that are on the Home Office list of 'Proscribed terrorist groups or organisations?
- not entered -

Indicators of risk

Involves potentially vulnerable participants? No
Involves potentially highly sensitive topics? No

Section C: Summary of research

1. Aims & Objectives

The overall aim of this project is to improve understanding related with attitudes, concerns, and opinions of health professionals towards application of sensor-based platforms for continuous and remote monitoring of chronic diseases in healthcare system of developing regions. More specifically this project aims to identify the requirements that may affect development, implementation and application of sensor-based platforms in developing regions. The overarching research question that this study will try to answer is:

- How can the application of sensor-based networks address the needs of healthcare professionals and healthcare centres in developing regions?

By answering above question, this study anticipates that it will be able to propose a unique, flexible and affordable sensor-based architecture that will suite developing regions' needs, conditions and help them in managing the increasing number of patients diagnosed with chronic conditions. Moreover, this will help to meet the following objectives:

- Investigate health professionals' perceptions related with the application of sensor-based networks in healthcare
- Identify factors leading to successful application of sensor-based networks in a developing country
- Elaborate health policies and health system in developing regions
- Identify factors that can that can challenge the implementation of sensor-based networks in health system of a

developing country

In this way the study will help to ensure that health professionals' opinions, recommendations, and concerns are considered prior to proposing the sensor-based architecture.

1. Methodology

This study has proposed to use qualitative approach as a research method because of the few previous research studies conducted to understanding patients' and medical staff' attitudes, perceptions, and opinions, prior to proposing the sensor-based applications (this is also one of the general reasons for using qualitative research proposed by Flick, 2007). Moreover, in public healthcare centres of Kosovo, our case study, sensor-based networks are not applied for treatment or management of chronic diseases. Therefore, qualitative research will help to better understand the benefits, needs, and limitations of applying sensor-based architectures for continuous monitoring of chronic diseases in developing countries.

The qualitative research is designed by primarily choosing the investigation place which will be within the University Clinical Centre of Kosovo (UCCK) where are located all clinics that provide tertiary healthcare. Hence within the UCCK, specifically in the Haematology, Endocrine, Nephrology and Cardiology Clinics, this study will interview health professionals and nurses that deal with treatment and management of chronic diseases. Semi structured interviews will be used as data collection tools, this due to possibility of open ended questions. Some general categories of questions that will be included during the interview are: demographic questions, questions related with knowledge about information technology, questions related with chronic disease parameters that need continuous monitoring (in this way the study will identify hardware components that the architecture will have), and questions related with usage of sensor networks for treatment and management of chronic diseases in developing regions. Hence the study will not have questions related with personal details about participants and no details about patients will be asked. In the end, gathered data will be analysed sequentially and separately. The study may use computer assisted programs like Nvivo to present data more briefly and easy the process of identifying codes and categorizing data.

This research study is concerned with understanding health professionals' experiences, attitudes, and the meaning of the phenomena under investigation, leading in this way to adoption of interpretative phenomenography as a methodological framework. In this way phenomenography will help us to proceed with the research and perceive, or understand perceptions about the phenomena under investigation (Richardson, 1999). This approach is used in various studies that had to do with medical and healthcare research (Stenfors-Hayes, 2013).

It is anticipated that the outcome from interview study, will help to conclude on the need for continuous and remote monitoring of chronic conditions. Moreover, this implies a better understanding of health professionals' opinions, their concerns, experiences and recommendations, before proposing the sensor-based architecture.

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Stenfors-Hayes T., Hult H., Dahlgren M.A. (2013). A phenomenographic approach to research in medical education. Med Educ. 47(3):261-70. doi: 10.1111/medu.12101

2. Personal Safety

Have you completed your departmental risk assessment procedures, if appropriate?

- not entered -

Raises personal safety issues?

No

- not entered -

Section D: About the participants

1. Potential Participants

This research study will primarily investigate health professionals' (doctors and nurses) attitudes to using sensor-based technologies in treating and continuously managing chronic diseases. Therefore, the participants will be clinicians located in the four clinics of University Clinical Centre of Kosovo (UCCK), more specifically: Haematology, Nephrology, Endocrine, and Cardiology.

In these clinics there are around 54 doctors, and 84 nurses, and it is anticipated that approximately 20 to 30 of them will be interviewed for this research. Potential participants will be identified based on their profile, qualification, and experience in the specific medical area. This study aims to have a variety of interviewees; therefore it will try to have a variety of gender, age and people that may already have experience with sensor-based platforms (private healthcare sector, or outside of Kosovo).

Potential interviewees will be identified from the list of personnel which is available online in the website of University Clinical Centre of Kosovo (University Clinical Center of Kosova, 2016).

References
University Clinical Center of Kosova. (2016). QKUK. Retrieved May 10, 2016 from: http://shskuk.org/#qkqk

1. Recruiting Potential Participants

In Kosovo, where the study will take place, all medical institutions provide publicly available lists of staff (Haematology Clinic, Nephrology Clinic, Endocrine Clinic, Cardiology Clinic, 2016). Therefore, this study will try to identify possible participants from these lists. If the lists do not contain all needed information, the researcher will contact the director of statistical department within the University Clinical Centre of Kosovo for further details.

All potential participants will be invited to participate in this research study through email. Those who want to participate will be asked to reply back to the researcher. The information sheet and consent form will be sent by email to healthcare professionals who have expressed interest to participate in the interview study prior to the interviews. They will be asked to carefully read the information sheet. Before the interview, participants will have the possibility to go through the information sheet together with the researcher and ask questions. After clarifying possible concerns, the researcher will kindly ask the interviewee to sign the consent form. Following these procedures, interviewees will be asked to start the interviewing process which will last approximately 30 to 40 minutes.

Once potential participants have been identified and the above mentioned procedures have been performed, the researcher will select 5 health professionals for pilot study. The idea of pilot study is to review the interview questions, refine the interview schedule, and to ensure that relevant data are being obtained.

After the pilot phase, this research will continue with the interview schedule and the rest of the selected participants based on the predefined sampling criteria (for example gender, age, years of experience, possible previous experience with sensor-based applications).

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CardiologyClinic-ShSKUK. (2016). Retrieved May 12, 2016 from: http://shskuk.org/klinika-e-kardiologjise/

1.1. Advertising methods

Will the study be advertised using the volunteer lists for staff or students maintained by CiCS? No

- not entered -

2. Consent

Will informed consent be obtained from the participants? (i.e. the proposed process) Yes

This research study will use an information sheet and consent form. Hence, when potential participants will contact back (reply back in the invitation email) the researcher to indicate that they would like to take part, the researcher will send them by email the information sheet and consent form. Potential participants will be asked to read carefully the information sheet prior to the interview. They will also be given the opportunity to ask questions. In this way the study will ensure that interviewees have understood the idea of the research and are willing to participate voluntarily in this research study.

A time will be arranged for the interview, during which the researcher together with the interviewee will go through the information sheet and answer possible questions that the interviewee may have. After this, the researcher will ask kindly the interviewee to sign the consent form.

The consent form will indicate that the interviewee is aware that his/her data will be used only for research purposes and will be strictly safe. Moreover, the interviewee will be aware that his/her interview will be recorded and then transcribed using anonymised names. Therefore, the form includes confirmation statements regarding idea of the research, voluntary participation, awareness of interview recording and statement that ensures data security of interviewees. The interviewee will need to check each of these statements and sign this form at the end. A copy of the form will be provided to the researcher and another one to the interviewee.

3. Payment

Will financial/in kind payments be offered to participants? No

1. Potential Harm to Participants

What is the potential for physical and/or psychological harm/distress to the participants?

It is unlikely that the participants will experience any physical and/or psychological harm/distress because the researcher will just be asking them about the application of sensor-based platforms for remote management of chronic diseases and the benefits it might have for their patients. The questions will be non-intrusive and participants need not answer any specific questions (if they do not feel comfortable to do so), and they can at any time withdraw from the study.

How will this be managed to ensure appropriate protection and well-being of the participants?

This study will take interviewees' consent related with recording of the interview. Recorded data will be strictly safe and used only for research purposes. Furthermore, interviewees' relevant personal information will be replaced with anonymised ones (for example false names) in order to protect information security and they will not be published or used during the research process.

Section E: About the data

1. Data Confidentiality Measures

While transcribing each interview, the researcher will use anonymised names for each participant. Moreover, the interviews will not collect personal details about participants and no details about patients will be asked.

2. Data Storage

Interview data will be collected using an audio recorder and then they will be transcribed into a word document. Recorded and transcribed data will be strictly safe and used only for research purposes.

The data will be gathered, and analysed by the main researcher who will take the full responsibility for the control of, and will act as the custodian for all the gathered data. The other only person who may have access to these data may by the supervisors who can advice on data analyses process.

The study may also use computer assisted programs like Nvivo to present data more briefly and easy the process of identifying codes and categorizing data. All these files will be held securely on two password-protected devices, personal laptop and a desktop; this because of the back up in case of data loses.

Section F: Supporting documentation

Information & Consent

Participant information sheets relevant to project? Yes

Document 1018894 (Version 2)	All versions
Document 1020088 (Version 1)	All versions

Consent forms relevant to project? Yes

Document 1018895 (Version 1)	All versions

Additional Documentation

External Documentation

- not entered -

Section G: Declaration

Appendix A.2 Study 1, Ethical Approval letter from the Research Ethics Committee of the University of Sheffield

The University Of Sheffield.

Downloaded: 23/09/2016
Approved: 23/09/2016

Adelina Basholli
Registration number: 130246147
Information School
Programme: Information Studies

Dear Adelina

PROJECT TITLE: Wireless monitoring systems for enhancing national health services in developing regions
APPLICATION: Reference Number 008335

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 23/09/2016 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 008335 (dated 18/08/2016).
- Participant information sheet 1020088 version 1 (22/06/2016).
- Participant information sheet 1018894 version 2 (22/06/2016).
- Participant consent form 1018895 version 1 (29/05/2016).

The following optional amendments were suggested:

Suggested (i.e. not required) amendments have been identified by reviewers: i) The information sheet could provide a little more detail about the themes that will be explored in the interview. ii) There is a need to be clearer on data/reporting anonymisation and data storage/security, as specified above. Please consider these points, and you may wish to discuss them with your supervisor. However, the research may proceed as outlined without further approval.

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Matt Jones
Ethics Administrator
Information School

Appendix A.3 Study 1, Ethical Approval letter from the American Hospital in Kosovo

Spitali Amerikan

Date: 02 - 10 - 2016

Prishtina

American Hospital Ethics Approval Form

Ethics committee within the American Hospital of Prishtina, approves Adelina Basholli's request to perform a research related to her doctoral studies:

Wireless monitoring systems for enhancing national health services in developing regions

This approval includes interviews with medical and administrative staff that are dealing with chronic diseases. The research process includes interviews that will be held in time and place agreed from both parties. Gathered data will be used only for research purposes related with this doctorate study.

The interviewer will contact possible interviewees through e-mail. After this, Interested participants will be informed about the aim of the study. The interviewees will be offered needed information prior to the interviews. All the gathered data will be safe and secure, and participant's identity will be anonymized. The research results can be published in online publications, international conferences or journals.

Approved from:

KOSOVA SPITAL AMERIKAN KOSOVE SPITALI

Appendix A.4 Study 1, Confirmation for changing the setting of the research

My Ethics Application

Matt Jones <matthew.l.jones@sheffield.ac.uk> Tue, Oct 25, 2016 at 5:16 PM
To: Adelina Basholli <adbasholli@seerc.org>
Cc: Larah N Arvandi <larah.hogg@sheffield.ac.uk>, Peter A Bath <p.a.bath@sheffield.ac.uk>

Dear Adelina,
cc Larah, Peter,

Thank you for your email.

Firstly, with regards to the changing from a public hospital to a private hospital as described, the School is satisfied that this constitutes a minor change to the research. As such, your research may continue as described without further ethical approval. You are advised to retain a copy of this email for your records. You mention in your email that you have obtained approval from the private hospital - would you be able to forward that certificate onto ischool_ethics@sheffield.ac.uk for our records?

As your ethics application has already been approved, it cannot be changed on the online system, but minor changes (such as the one described) can be approved by email.

If you intend to make any further changes to your research design, please contact ischool_ethics@sheffield.ac.uk. You must receive approval for any changes **before** conducting the research.

Finally, regarding adding information to your application - this is not possible as, as mentioned above, your application has already been approved. The amendments suggested by the reviewers are points to consider, but you don't need to update your application.

I hope this helps - please let me know if you require anything further,

Matt

Matt Jones

Research Support Manager, (Wednesdays and
Thursdays) Department of Economics,
The University of Sheffield, Room 432, 9 Mappin Street, Sheffield, S1 4DT,

+44 (0)114 2229189
www.sheffield.ac.uk/economics

Research Officer (Tuesdays
and Fridays) Information
School,
The University of Sheffield, Room 230, Regent Court, 211 Portobello, Sheffield, S1 4DP

+44(0)114 222 6346
www.sheffield.ac.uk/is

Appendix A.5 Study 1, Information Sheet

South-East European Research Centre (SEERC) - University of Sheffield
Information School
Address: SEERC, 24 Proxenou Koromila Street, 54622, Thessaloniki, Greece
Contact: adbasholli@seerc.org, abasholli1@sheffield.ac.uk, 00377 45 398 775

Information sheet

Title of the project
Wireless monitoring systems for enhancing national health services in developing regions

Invitation paragraph
You are kindly asked to take part in this research project. We have prepared an information sheet to help you understand better the idea of the research, why it is being done, and what it will involve. Please take time to read provided information carefully and decide whether you want to participate or not. In case you need further information or have any questions please let us know. Thank you.

What is the project's purpose?
This research project plans to investigate the opinions of health professionals related to the application of sensor-based networks in healthcare. Sensor-based networks present architectures of sensor nodes that can sense information. In the healthcare domain, they can collect health data, for example, blood pressure, heart rate, oxygen saturation, blood sugar, etc. Through this research, this project aims to investigate health professionals' attitudes to using sensor-based technologies, to propose a flexible, affordable and feasible solution for continuous and remote monitoring of chronic diseases in developing regions, and Kosovo in particular.

Why have I been chosen?
The sensor-based architecture that this project aims to propose is related to chronic diseases and their remote and continuous monitoring through sensor-based applications, e.g., having an application that can continuously record patients' blood pressure through sensors. Therefore, it is important to understand health professionals' opinions, attitudes, and willingness to use such platforms. From a list of health professionals, we have selected doctors and nurses who have experience and background in managing and treating chronic diseases in Kosovo.

Do I have to take part?

This study is part of the PhD studies of Adelina Basholli. Therefore, if you take part, it would help me in making recommendations for the design of sensor-based systems. However, you are free to decide for yourself whether you wish to participate or not.

What will happen to me if I take part?

If you are willing to take part in the study, it will involve having a semi-structured interview with me; during this, I will ask you a series of questions about your work and how sensor-based systems might support you and your patients. The interview will last approximately 30-40 minutes and the aim of the interviews is to understand your views of remote and continuous monitoring of chronic illnesses.

Would there be any implications if I participate/I do not participate in this study?

If you wish to participate you would contribute to the overall research results of this PhD study. The information provided during the interviews will be kept strictly confidential and your name will be anonymised. The data will be used for this PhD study and possibly in future research. Your participation is based on your voluntary willingness; therefore there are not any implications if you do not want to participate.

Will I be recorded, and how will the recorded media be used?

Your research data will be collected through audio-recorded interviews and then they will be coded (anonymised) so that the identity of each participant will be replaced with an anonymised name. These recordings will be transcribed and analysed. Only the researcher involved in this PhD process may have access to the original recording, although my research supervisors will have access to the transcriptions.

Can I withdraw from the study?

If at any point up to when I start analysing the data, you do not wish to continue with the study, you can withdraw from the study. This will not have any consequences for you as a participant. You are asked to participate voluntarily, thus if you want to withdraw you do not need to provide any reason for that. After I have started analysing the data, it will not be possible to withdraw, because it will not be possible to separate data/results from different people.

How are the data provided by me going to be used?

The interview data will be used for research purposes related to my PhD. This includes analysing the data across all the interviews and critically evaluating and interpreting the results. Anonymised quotations and the study findings and conclusions may be published in my PhD, and research articles, conferences or journals.

Will my taking part in this project be kept confidential?

The research data will be coded so that the identity of each participant will be replaced with an anonymised name. The information provided during the interviews will be kept strictly confidential and will be used for this PhD study and possibly in future research. It will not be possible for any participants to be identified in any publication or report.

Who has ethically reviewed the project?

This research project has been ethically approved via the Information School ethics review procedure, following the University of Sheffield research ethics policy.

Contact person for any outstanding queries

If you have any further queries you can contact the researcher Adelina Basholli (email: adbasholli@seerc.org), or the study supervisor: Dr Thomas Lagkas at the SEERC (email: tlagkas@city.academic.gr) and Prof. Peter Bath (email: p.a.bath@sheffield.ac.uk).

Thank you for taking part in this project!

Appendix A.6 Study 1, Consent Form

South-East European Research Centre (SEERC) - University of Sheffield
Department of Information School
Address: 24 Proxenou Koromila Street, 54622, Thessaloniki, Greece
Contact: adbasholli@seerc.org, abasholli1@sheffield.ac.uk, 00377 45 398 775

Consent form

Title of the project

Wireless monitoring systems for enhancing national health services in developing regions

Details of the researcher

Adelina Basholli, PhD candidate at Information School, University of Sheffield, and South-East European Research Centre
Direct contact through phone: +377 45 398 775 or by email: adbasholli@seerc.org

1. I confirm that I have read and understood the Information Sheet that explains in detail the purpose of this project ☐
2. I confirm that I agree to participate voluntarily in this study ☐
3. I understand that I am free to withdraw from the study at any moment and I may not answer particular questions ☐
4. I am aware that the interview will be audio-recorded and I agree with this ☐
5. I confirm that these recorded materials can be transcribed and used for research purposes during this PhD thesis ☐
6. I am aware of the anonymity of the provided information and that pseudonyms will be used during the transcription process ☐
7. I understand that the data provided during the interview will be stored safely and securely ☐
8. I agree that the data may be used in future research ☐

Participant details:	Researcher details:
Name ____________________	Name ____________________
Signature ____________________	Signature ____________________
Date ____________________	Date ____________________

Appendix A.7 Study 1, Demographic questionnaire

Demographic questionnaire

Please kindly consider answering the following demographic information. You can answer by yourself, or the information can be provided by a family member or relevant.

All the provided information will be confidential.

1. Gender Female ☐ Male ☐

2. Age
   - 18-24 ☐ 45-54 ☐
   - 25-34 ☐ 55-64 ☐
   - 35-44 ☐ 65+ ☐

Health professional related questions

3. Education level
   - University degree ☐ Medical High school ☐
   - Specialization degree ☐
   - Other certifications ______________________

4. Working in Private sector ☐ Public sector ☐

5. Working experience
   - 6 months-1 year ☐ 2.5-3 years ☐
   - 1.5-2 years ☐ More than 3 years ☐

6. Use of Information Technology
   - Laptop ☐ Desktop ☐ Smart phones ☐
   - None ☐

   a. How often:
   - Daily ☐ Once per day ☐ Weekly ☐
   - Once per week ☐ Monthly ☐

Appendix A.8 Study 1, Interview Guide

Pre-interview:

1. Thank you, introduction to the research and idea of the interviews
2. Information sheet
3. Possible questions
4. Consent form

Interview:

1. Setting the interview context

   I would like to start this interview by thanking you again for kindly agreeing to take part in my study. First, I would like to get more information about your daily work. This would help for understanding your perception about the application of devices that would facilitate and help you in your day-to-day work.

   1. I would like to have some background information about you; therefore can we please go through the demographic questionnaire and fill in some details regarding your age, education, experience, specialization, and usage of information technology. Thank you!

   2. Could you please tell me more about your work?
      a). How would you describe a typical day in your job role?

   3. Would you like to tell me something about your patients?

      a). On average how many patients do you monitor per day?

      b). What are the most frequent diseases or symptoms that you encounter/monitor?

      c). Do you have more patients coming from rural areas or urban ones?

      d). Typically, what are the age groups of your patients? What is the average age of your patients?

2. Application of information technology in healthcare

   Can we please talk more about the work that you are doing to come up with the practice of computers, laptops or mobile devices in your daily life and for work purposes.

1. What are the best symptoms for early detection of worrying conditions while dealing with chronic diseases?

2. While examining your patients, what measures (vital signs)/data do you collect?

   a). How often do you measure them?

   c). Which values of chronic parameters/vital signs do you see as serious cases? (for example, worrying values for blood pressure (or similar) in various profiles of your patients)

   d). How do you communicate these measures to the patient? Or to other health care professionals?

   e). How do you record or process the patient's status for clinical processes? (do you write them on paper?)

3. Generally, how well do you think that the application of computers will facilitate the process of transcribing patient data?

   a). Is there any reason why you have not used the computers until now? If, yes, what?

   b). How do you think using computers instead of a paper-based system would facilitate your work?

   c). How do you think the application of computers or mobile phones would change the way of working you were doing until now? What about managing the disease process? (for example, if you would have a program where you could write all the information related to the patient and the patient could have access there too)

4. While monitoring your patient what kind of facilities/technology/devices do you use?

   a). Could you please provide more details about the technology you are using to monitor your patients?

   b). What do you see as an advantage of using this technology?

   c). How did you find the process you went through when you first started using this technology? What was easy about it, what was difficult?

   d). What do you see as a disadvantage of using this technology?

e). What would you suggest related to the technology you are using?

3. Introduction to remote monitoring technologies

If we think about the advantages that computers, laptops or mobile devices may provide in your daily work, I would like to talk more about this and the possibility of monitoring patients from a distance, for example in their homes, offices, or similar.

1. Could you please let me know more about your experience with monitoring your patients from a distance? By distance, I mean getting patients' vital signs measured by them in their own homes so that you could just comment on them.

   a). Could you please elaborate on any scenario where you have communicated with your patient from a distance? E.g., by telephone, email, etc.?

   b). In case you exchange emails or short messages, what information have they contained?

2. How do/would you feel to monitor a patient from a distance? Imagine him/her having a device that could measure his/her blood pressure and send these data to you.

   a). What kind of implications will this have for your work?

   b). Do you think this would reduce the number of clinical visits or hospitalization days?

3. Would you as a health professional give feedback and respond to the gathered patient data?

   a). What sort of information would you like your patient to send to you to provide reliable feedback?

   b). Could you please elaborate on the means you would prefer to get your patient's data so that you could easily provide feedback? (for example, would you like to receive alert messages on your mobile phone when your patient has high blood pressure, or would you like to receive a weekly report of summarized measures of your patient in your email)

   c). What might limit your willingness to provide feedback to your patients at a distance?

4. Usage of sensor networks for treatment and management of chronic diseases

While mentioning monitoring from a distance, this can be done through sensors. Sensors can sense information or collect data. In healthcare, sensors can collect/measure health data (vital signs), for example, blood pressure, heart rate, oxygen saturation, etc. So, for example, sensors can read your patients' blood pressure (and similar) and then we can provide a means of presenting these measures to you. Now I would like to talk more about using sensors for managing chronic diseases.

1. Could you please let me know if you have any experience with sensor applications? (for example, there exist applications in our smartphones that can read blood pressure values when we press the camera component with our finger)

2. How would you feel about applying sensors to help you measure your patient's vital signs and get this information displayed later on?

3. How do you think monitoring provided by sensor-based applications could be used to provide the information you need (for example, the vital signs that you monitor)?

4. What might be the possible implications of using sensor-based networks for continuous monitoring of chronic conditions?

5. How could you as a health professional have an impact on the use of sensor-based platforms by your patients?

6. How could you use sensor-based data in a clinical setting and for clinical decision-making?

   a). How your decisions will be modified by the information gathered from the sensor-based applications?

5. What may be the potential benefits of using sensor-based applications in monitoring chronic conditions?

6. How would you like these data to be presented to you (information displayed appropriately)?

7. What do you see as a potential drawback of using a sensor-based application in monitoring chronic conditions?

8. How would you feel about medical errors due to the usage of sensor-based networks?

9. Would you prefer the usage of sensor-based applications only at home or within hospital premises?

5. Additional questions

Finally, I would like to summarize the interview with some general questions related to your opinion of applying sensor-based devices within your clinic.

1. Could you describe a successful implementation of a sensor-based application for chronic disease monitoring in your clinic?

2. What do you see as a challenge for the implementation of sensor platforms in your clinic?

    a). How could we overcome these challenges?

3. How do you think sensor-based devices may lower treatment costs related to chronic diseases?

    a). What about hospital visits?

    b). Or hospitalization days?

4. How do you think sensor-based applications would improve patient's life?

5. Do you think there is also something we did not cover, and that would be of interest?

I would like to thank you again for being part of this investigation. I appreciate your time and willingness to take part.

Appendix A.9 Study 1, Email to healthcare professionals

South-East European Research Centre (SEERC) - University of Sheffield
Information School
Address: 24 Proxenou Koromila Street, 54622, Thessaloniki, Greece
Email: adbasholli@seerc.org, abasholli1@sheffield.ac.uk
Mobile 00377 45 398 775

15th May 2016

Dear Doctor/Nurse,

I am writing to you to ask if you will kindly help me with some research that I am doing. My name is Adelina Basholli and I doing my research degree at the South-East European Research Centre- University of Sheffield. My research topic has to do with the proposal of a unique, flexible, and cost-effective sensor-based architecture that will help developing regions manage and treat easier chronic diseases.

Successful proposal and implementation of a sensor-based application for monitoring chronic conditions in developing regions are closely related to health professional's attitude and acceptance of this technology in healthcare. The study that I am inviting you to participate in, will look at the opinions, attitudes and possible concerns of medical staff towards the application and usage of sensor-based platforms that will enable remote and continuous monitoring of chronic diseases.

If you would like to participate in this research study, I will be available to interview you in a daytime and in the location that suits you. The interview will take approximately 30 minutes and it will include questions related to: knowledge about information technology, chronic disease parameters that need continuous monitoring, and usage of sensor networks for treatment and management of chronic diseases. Attached you may find the Consent Form and Information Sheet that include detailed information about the study. If you are interested in participating in this research study, please e-mail me back or call me and we can arrange the interview at your preferred time, date and location.

Your participation would contribute to the overall research results, make easier the proposal of a cost-effective sensor-based architecture for developing regions- Kosovo as a case study here, and help me with the research studies.

Yours Faithfully,
Adelina Basholli

Appendix B.1 Study 2, Ethics Application (no. 023943)

Application
023943

Section A: Applicant details

Date application started:
Tue 27 November 2018 at 19:38

First name:
Adelina

Last name:
Basholli

Email:
abasholli1@sheffield.ac.uk

Programme name:
Information Studies

Module name:
Information Studies

Last updated:
20/07/2020

Department:
Information School

Applying as:
Postgraduate research

Research project title:
Wireless monitoring systems for enhancing national health services in developing regions

Has your research project undergone academic review, in accordance with the appropriate process? Yes

Similar applications:
- not entered -

Section B: Basic information

Supervisor

Name	Email
Peter Bath	p.a.bath@sheffield.ac.uk

Proposed project duration

Start date (of data collection): Wed 1 July 2020

Anticipated end date (of project) Tue 1 December

Project code
- not entered -

Suitability

Takes place outside UK?
Yes

Involves NHS?
No

Health and/or social care human-interventional study?
No

ESRC funded?
No

Likely to lead to publication in a peer-reviewed journal?
Yes

Led by another UK institution?
No

Involves human tissue?
No

Clinical trial or a medical device study?
No

Involves social care services provided by a local authority?
No

Involves adults who lack the capacity to consent?
No

Involves research on groups that are on the Home Office list of 'Proscribed terrorist groups or organisations?
No

Indicators of risk

Involves potentially vulnerable participants?
No
Involves potentially highly sensitive topics?
No

Section C: Summary of research

1. Aims & Objectives

Sensor-based networks present architectures of sensor nodes that are able to sense information. In the healthcare domain, they can collect health data, for example, blood pressure, heart rate, oxygen saturation, blood sugar, etc. Through this research, we aim to evaluate the proposed sensor-based architecture that was developed and implemented based on healthcare professionals' feedback during the first phase of the research (initial interview study).

More specifically the objectives of the study are as follows:
a. To evaluate the user experience and feasibility of the proposed sensor-based platform,
b. To gain insights into healthcare professionals' understanding, usage, and effectiveness of the proposed system,
c. To review the proposed system if it meets healthcare professionals' needs for remote and continuous monitoring of patients with chronic diseases.

By achieving these objectives it is expected that a contribution will be made to the existing bodies of research within the fields of e-health, sensor-based platforms, and remote and continuous monitoring of chronic diseases. Further to this, the study may help to ensure that systems that are designed, developed, and implemented based on user perceptions and known organizational factors, could contribute in adoption, usage and success rates of digital technologies in healthcare, which in other hand affects improved healthcare services delivered to patients

1. Methodology

This research presents the second phase of a Ph.D. study and it builds upon an initial interview study conducted in December 2017 – February 2018, that aimed to investigate healthcare professionals' attitudes and perceptions on using sensor-based networks for remote and continuous monitoring of chronic diseases in a developing region, Kosovo as a case study. The findings of the first phase of research enabled the development and implementation of a feasible sensor-based platform. This current phase of research aims to apply task-based scenarios and qualitative interviews to get healthcare professionals' opinions and their feedback that will contribute to the evaluation of the proposed sensor-based architecture.

As a theoretical framework to form the questions of the interview, this study used a combination of variables from technology acceptance models such as Technology Acceptance Model 2 (TAM2) (Venkatesh and Davis, 2000), The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003), Task-Technology Fit (TTF) (Goodhue and Thompson, 1995) and truth-telling variable that emerged from the results of the first phase of research (Basholli, et al. 2020). Furthermore, this study will use task-based scenarios as in other similar studies (Stellefson, Chaney and Chaney, 2014; Kim, Kim, Lee and Chung, 2014), for evaluating prototypes within the healthcare domain.
In this way, this qualitative study will follow a task-based scenario where healthcare professionals will have some predefined tasks to perform with the system. Following that, healthcare professionals will be asked questions regarding their experience with the proposed sensor-based system. Hence, the interview guide includes questions based on variables such as perceived usefulness, perceived ease of use, subjective norm, behavioural intention, job relevance, performance expectancy, social influence, and truth-telling, which emerged as a new variable from the results of the first interview study with healthcare professionals. Semi-structured in-depth interviews will be used as data collection tools.

We aim to interview the same participants from the first interview study and get their feedback on the implemented sensor-based architecture. Hence, participants will include healthcare professionals of the American Hospital in Kosovo, that monitor parameters/vital signs related to chronic (i.e., long-term) diseases, for example, heart rate, pulse, blood pressure, oxygen saturation, and temperature. These participants will be contacted using emails that we previously obtained from the primary interview study, and through the Human Resource Manager of the hospital, who will inform us of the availability of the healthcare professionals. A pilot study will be conducted with 5 healthcare professionals, initially, and following recommendations and improvements of this pilot phase, the main study will continue with the rest of the participants. We will continue with the interviewing process up to a point that we will conclude that no new information is being generated or mentioned from the participants (data saturation point).
The data generated from this interview study will be processed using two software tools, Statistical Package for the Social Science (SPSS) and NVIVO. SPSS will be used to code and analyse demographic data. NVIVO will be used to import the transcripts and code the interview data. This study will use thematic analysis and generate themes to facilitate the process of data analysis (Braun and Clarke, 2006).

References:

Basholli, A., Lagkas, Th., Bath, P.A., Eleftherakis, G. (2020). Clinical acceptability of sensor-based networks for monitoring patients with chronic illnesses in a developing country. Journal of Biomedical Informatics. Manuscript submitted for publication.

Braun V and Clarke V (2006) Using thematic analysis in psychology. Qualitative Research in Psychology, 77-101. doi: 10.1191/1478088706qp063oa.
Goodhue, D.L., Thompson, R.L. (1995). Task-Technology Fit and Individual Performance. MIS Quarterly, 19(2):213-236.

Kim, J., Kim, J., Lee, D., Chung, K.-Y. (2014). Ontology-driven interactive healthcare with wearable sensors, Multimed Tools Appl. 71: 827. https://doi-org.sheffield.idm.oclc.org/10.1007/s11042-012-1195-9

Stellefson, M., Chaney, B., Chaney, D. (2014). Heuristic Evaluation of Online COPD Respiratory Therapy and Education Video Resource Center, Telemed J E Health. 20(10): 972–976. doi: [10.1089/tmj.2014.0009]

Venkatesh, V., Davis, F.D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. Management Science, 46(2), 186-204. http://dx.doi.org/10.1287/mnsc.46.2.186.11926

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D., (2003). User acceptance of information technology: Toward a unified view. MIS Quarterly. 27(3), 425–478.

2. Personal Safety

Have you completed your departmental risk assessment procedures, if appropriate? Not

applicable

Raises personal safety issues?

No

This research study does not raise any issues of personal safety for any of the researchers part of it. The study will investigate healthcare professionals' opinions on a proposed sensor-based platform. Moreover, the process has to do with people that deal with chronic diseases that do not impose any issues of interviewer personal safety. The interviews will be carried out in the hospital during normal working hours.

Section D: About the participants

1. Potential Participants

This study presents an evaluation research following the first phase of interviews that were already performed with the healthcare professionals. Hence, participants will include clinicians located in the different departments of the American Hospital in Kosovo, that participated in the first phase of this Ph.D. research. They will include healthcare professionals that monitor parameters/vital signs related to chronic (i.e., long-term) diseases, for example, heart rate, pulse, blood pressure, oxygen saturation, and temperature.

2. Recruiting Potential Participants

Participants will be contacted through emails that we got from them from the first interview study that they participated in and through the Human Resource Manager of the Hospital, who will inform us about healthcare professionals' availability to have the interview.
Five healthcare professionals that participated in the first phase of this Ph.D. research (primary qualitative study) will be contacted through emails to participate in the pilot study, initially, and following recommendations and improvements of this pilot phase, the main study will continue with the rest of the participants.

2.1. Advertising methods

Will the study be advertised using the volunteer lists for staff or students maintained by CiCS? No

- not entered -

3. Consent

Will informed consent be obtained from the participants? (i.e. the proposed process) Yes

This research study will use a consent form and provide introductory information prior to the interviewing process. Hence, participants will be asked to read carefully the introductory information, and then sign the Consent Form. They will also be given the opportunity to ask questions. In this way, the study will ensure that participants have understood the idea of the research and are willing to participate voluntarily in this research study. Furthermore, the consent form will indicate that the participant is aware that his/her data will be used only for research purposes and will be strictly safe

4. Payment

Will financial/in kind payments be offered to participants? No

5. Potential Harm to Participants

What is the potential for physical and/or psychological harm/distress to the participants?

It is unlikely that the participants will experience any physical and/or psychological harm/distress because the researcher will be asking them to perform some predefined tasks with the proposed sensor-based platform and then ask questions about their experience or get feedback for that system. The questions will be non-intrusive and participants can at any time withdraw from the study.

How will this be managed to ensure appropriate protection and well-being of the participants?

This study will take interviewees' informed consent related to the recording of the interview. Recorded data will be strictly safe and used only for research purposes. Furthermore, the interviewees' relevant personal information will be replaced with anonymised codes (for example, Interview 1. Doctor, Interview 2. Nurse) in order to ensure information security and confidentiality.
Interviewee's personal or identifiable information will not be published or used during the research process.

Section E: About the data

1. Data Processing

Will you be processing (i.e. collecting, recording, storing, or otherwise using) personal data as part of this project? (Personal data is any information relating to an identified or identifiable living person).

No

Please outline how your data will be managed and stored securely, in line with good practice and relevant funder requirements

Interview data will be collected using an audio recorder and then they will be transcribed into a word document. To avoid any risk of data loss a second device (Samsung S10+) may also be used for recording each interview as a backup device in case of a hardware error, recording malfunction, or other battery power/storage issues, etc. Recorded audio files will be transferred immediately after each interview and will be stored in a password-protected folder on an encrypted hard drive. After the successful transfer of the audio files to the hard drive, the voice recordings will be deleted from the other devices (audio recorder and Samsung).

The data will be gathered and analysed by the main researcher who will take full responsibility for the control of, and will act as the custodian for all the gathered data. The other only person who may have access to these data may be the supervisors who can advise on the data analysis process.

The study will use computer-assisted programs like SPSS and Nvivo to present data briefly and help in the process of identifying codes and categorizing data. All these files will be held securely on the password-protected folder inside the encrypted hard drive.

Section F: Supporting documentation

Information & Consent

Participant information sheets relevant to project?
Yes

Document 1080969 (Version 1) — All versions

Consent forms relevant to project?
Yes

Document 1080970 (Version 1) — All versions

Additional Documentation

Document 1081738 (Version 1) — All versions
Interview Guide with semi-structured and in depth interview questions.

Document 1080971 (Version 2) — All versions
Tasks that participants need to perform with the proposed sensor-based platform

External Documentation

- not entered -

Section G: Declaration

Signed by:
Adelina Basholli
Date signed:
Mon 20 July 2020 at 21:05

Appendix B.2 Study 2, Ethical Approval letter from the Research Ethics Committee of the University of Sheffield

The University Of Sheffield.

Downloaded: 07/09/2021
Approved: 20/07/2020

Adelina Basholli
Registration number: 130246147
Information School
Programme: Information Studies

Dear Adelina

PROJECT TITLE: Wireless monitoring systems for enhancing national health services in developing regions
APPLICATION: Reference Number 023943

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 20/07/2020 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 023943 (form submission date: 20/07/2020); (expected project end date: 01/12/2020).
- Participant information sheet 1080969 version 1 (22/06/2020).
- Participant consent form 1080970 version 1 (22/06/2020).

If during the course of the project you need to deviate significantly from the above-approved documentationplease inform me since written approval will be required.

Your responsibilities in delivering this research project are set out at the end of this letter.

Yours sincerely

Paul Reilly
Ethics Administrator
Information School

Please note the following responsibilities of the researcher in delivering the research project:

- The project must abide by the University's Research Ethics Policy: https://www.sheffield.ac.uk/rs/ethicsandintegrity/ethicspolicy/approval-procedure
- The project must abide by the University's Good Research & Innovation Practices Policy: https://www.sheffield.ac.uk/polopoly_fs/1.671066!/file/GRIPPolicy.pdf
- The researcher must inform their supervisor (in the case of a student) or Ethics Administrator (in the case of a member of staff) of any significant changes to the project or the approved documentation.
- The researcher must comply with the requirements of the law and relevant guidelines relating to security and confidentiality of personal data.
- The researcher is responsible for effectively managing the data collected both during and after the end of the project in line with best practice, and any relevant legislative, regulatory or contractual requirements.

Appendix B.3 Study 2, Ethical Approval letter from the American Hospital in Kosovo

Spitali Amerikan

Date: 07.04.2020

Prishtina

Ethics Approval Form

Ethics committee within the American Hospital of Prishtina approves Adelina Basholli's request to perform research related to her doctoral studies:

Wireless monitoring systems for enhancing national health services in developing regions

This approval includes interviews with medical and administrative staff that are dealing with chronic diseases. The research process includes interviews that will be held in time and place agreed by both parties. Gathered data will be used only for research purposes related to this doctorate study.

Medical personnel interested to participate will be informed about the aim of the study. Following that, interested interviewees to participate in the study will be demonstrated the sensor-based system for remote and continuous monitoring of chronically ill patients. Hence, the software platform that was implemented during this doctoral thesis, will be presented to interested interviewees. After the demo of the system, interviewees will be asked about their opinions and experiences with the implemented platform.

The interviewees will be offered needed information prior to the interviews. All the gathered data will be safe and secure, and the participant's identity will be anonymized. The identity, or any other personal information that may reveal their identity, will be replaced with corresponding codes (for example, Interview 1, nurse) and will be used like this throughout the research project. The research results can be published in online publications, international conferences or journals.

Approved from:

American Hospital Kosova
Igli LARASHI, BSc, MSc
Executive Director

Appendix B.4 Study 2, Information Sheet

South-East European Research Centre (SEERC) - University of Sheffield
Information School
Address: SEERC, 24 Proxenou Koromila Street, 54622, Thessaloniki, Greece
Contact: abasholli1@sheffield.ac.uk, adbasholli@seerc.org, 00383 45 398 775

Information sheet

Title of the project
Wireless monitoring systems for enhancing national health services in developing regions

Invitation paragraph
You are kindly asked to take part in this research project. We have prepared this information sheet to help you understand better the idea of the research, why it is being done, and what it will involve. Please take the time to read the provided information carefully and decide whether you want to participate or not. In case you need further information or have any questions please let us know. Thank you.

What is the project's purpose?
This research project plans to investigate the opinions of health professionals related to the proposed sensor-based platform for application in the healthcare domain. The proposed sensor-based architecture aims to provide remote and continuous monitoring for chronically ill patients. Through this research, this project aims to investigate health professionals' attitudes and opinions after using the proposed software platform that enables remote and continuous vital sign monitoring.

Why have I been chosen?
This research project presents a follow-up study on the opinions of health professionals related to the proposed sensor-based platform for application in the healthcare domain. Results of the first interview study helped to propose a sensor-based platform for remote and continuous monitoring of patients with chronic illnesses. Hence, as you participated in the first phase of this research and contributed with your opinions, we would now like to have your feedback on the proposed platform, if you agree to participate in this evaluation phase.

Do I have to take part?
This study is part of the PhD studies of Adelina Basholli. Therefore, if you take part, you would help to further enhance and better evaluate the proposed sensor-based platform. However, you are free to decide for yourself whether you wish to participate or not.
What will happen to me if I take part?

If you are willing to take part in the study, it will involve having a demo of the proposed system and following that, a semi-structured interview. During this interview, you will be asked a series of questions related to the proposed platform. The interview will last approximately 35-45 minutes and the aim of the interviews is to get feedback and evaluation comments on the proposed sensor-based architecture.

Would there be any implications if I participate/I do not participate in this study?
If you wish to participate you would contribute to the overall research results of this PhD study. The information provided during the interviews will be kept strictly confidential and your personal details will be anonymized. The data will be used for this PhD study and possibly in future research. Your participation is based on your voluntary willingness; therefore, there are not any implications if you do not want to participate.

Will I be recorded, and how will the recorded media be used?
Your research data will be collected through audio-recorded interviews and then they will be coded (anonymized) so that the identity of each participant will be replaced with an anonymized name. These recordings will be transcribed and analysed. Only the researcher involved in this PhD process may have access to the original recording, although the research supervisors will have access to the transcriptions.

Can I withdraw from the study?
If at any point up to when we start analysing the data, you do not wish to continue with the study, you can withdraw from the study. This will not have any consequences for you as a participant. You are asked to participate voluntarily, thus if you want to withdraw you do not need to provide any reason for that. After we have started analysing the data, it will not be possible to withdraw, because it will not be possible to separate data/results from different people.

How are the data provided by me going to be used?
The interview data will be used for research purposes related to this PhD. This includes analysing the data across all the interviews and critically evaluating and interpreting the results. Anonymized quotations and the study findings and conclusions will be published in the thesis of this PhD and may be published in research articles, conferences or journals.

Will my taking part in this project be kept confidential?
The research data will be coded so that the identity of each participant will be replaced with an anonymized name. The information provided during the interviews will be kept strictly confidential and will be used for the purposes of this PhD study and possibly in future research. It will not be possible for any participants to be identified in any publication or report.

Who has ethically reviewed the project?
This research project will be ethically approved via the Information School ethics review procedure, in accordance with the University of Sheffield research ethics policy.

Contact person for any outstanding queries

If you have any further queries you can contact the researcher Adelina Basholli (email: adbasholli@seerc.org), or the study supervisor: Prof. Peter Bath (email: p.a.bath@sheffield.ac.uk) and Dr Thomas Lagkas (email: tlagkas@citycollege.sheffield.eu).

Thank you for taking part in this project!

* This document will be translated also in the Albanian language, as the native language of participants

Appendix B.5 Study 2, Consent Form

SOUTH-EAST EUROPEAN RESEARCH CENTRE

The University Of Sheffield.

South-East European Research Centre (SEERC) - University of Sheffield
Department of Information School
Address: 24 Proxenou Koromila Street, 54622, Thessaloniki, Greece
Contact: adbasholli@seerc.org, abasholli1@sheffield.ac.uk, 00377 45 398 775

Consent form

Title of the project
Wireless monitoring systems for enhancing national health services in developing regions

Details of the researcher
Adelina Basholli, PhD candidate at Information School, University of Sheffield, and South-East European Research Centre
Direct contact through phone: +383 45 398 775 or by email: abasholli1@sheffield.ac.uk, adbasholli@seerc.org

1. I confirm that I have read and understood the Information Sheet that explains in detail the purpose of this project ☐
2. I confirm that I agree to participate voluntarily in this study ☐
3. I understand that I am free to withdraw from the study at any moment and I may not answer particular questions ☐
4. I am aware that the interview will be audio-recorded and I agree with this ☐
5. I confirm that these recorded materials can be transcribed and used for research purposes during this PhD thesis ☐
6. I am aware of the anonymity of the provided information and that pseudonyms will be used during the transcription process
7. I understand that the data provided during the interview will be stored safely and securely ☐
8. I agree that the data may be used in future research ☐

Participant details:	Researcher details:
Name ______________________	Name ______________________
Signature ___________________	Signature ___________________
Date ______________________	Date ______________________

Appendix B.6 Study 2, Demographic questionnaire

South-East European Research Centre (SEERC) - University of Sheffield
Information School
Address: SEERC, 24 Proxenou Koromila Street, 54622, Thessaloniki, Greece
Contact: abasholli1@sheffield.ac.uk, adbasholli@seerc.org, 00383 45 398 775

Demographic questionnaire*

Participated in the first interview study?	Yes ☐ No ☐
Gender	Female ☐ Male ☐
Age	18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65+ ☐
Working as:	Nurse ☐ Doctor ☐ Other ________
Work experience (overall, i.e., in you working life)	< 1 year ☐ 1 - 2 years ☐ 2 - 5 years ☐ 5 - 10 years ☐ 10 - 20 years ☐ > 20 years ☐
Experience with digital technologies (PC, Laptop, mobile phone)	Yes* ☐ No ☐
	*If yes, please let us know how often do you use them?
	Daily basis ☐ Weekly basis ☐ Month basis ☐
Experience in monitoring patients at a distance	Yes* ☐ No ☐
	*If Yes, please select the ones that apply as below:
	Communication through phone ☐
	Readings of vital signs while the patient is at a distance ☐
	Having a patient's vital signs recorded by a remote device ☐

* This document will be translated also in the Albanian language, as the native language of participants

Appendix B.7 Study 2, Interview Guide

Interviews with health professionals to evaluate the proposed sensor-based platform

* This document will be translated also in the Albanian language, as the native language of participants

Pre-interview:

1. Thank you, introduction to the research and idea of the interviews
2. Information sheet
3. Possible questions
4. Consent form
5. Tasks to be performed with the system

Interview:

1. Setting the interview context

I would like to start this interview by thanking you again for kindly agreeing to take part in my study. First, I would like to get more information about your experience with the proposed sensor-based platform, that you just performed some tasks with it. This would help for understanding your opinions, comments, and get feedback on the proposed sensor-based platform.

1. I would like to have some background information about you; therefore, can we please go through the demographic questionnaire and fill in some details regarding your age, education, experience, specialization, and usage of information technology. Thank you!
2. Could you please tell me more about your overall experience with the sensor-based platform, that you already performed some tasks with.

   a). How would you describe a typical working scenario with this sensor-based platform?

   b). Have you used any similar system before?

   If yes, how would you compare the system you used before with the proposed sensor-based platform?
3. Could you please tell me more about the application of the proposed sensor-based platform?

   a). How do you find the application of the proposed sensor-based platform in your clinic? Would your colleagues support and use it?

   b). How do you find the application of the proposed sensor-based platform in every healthcare institution in our country, considering Kosovo as a developing country? Would other healthcare professionals apply it?

   c). How do you think, the application of the proposed sensor-based platform, would affect your working schedule?

d). How do you think, the application of the proposed sensor-based platform, would affect your workload?

e). How do you think, the application of the proposed sensor-based platform, would affect the prescriptions of the therapies, for remote monitoring patients?

f). Overall, how do you think the application of the proposed sensor-based platform would affect the healthcare systems of developing regions.

2. Evaluation of the proposed sensor-based platform

Can we please talk more about the tasks you performed with the proposed sensor-based platform, to come up with some important parameters that need consideration especially when applying digital technologies in healthcare settings.

2.1 Suitability for the task

1. Could you please tell me more about the functionalities that are relevant to fulfil a task? Tasks include actions that you as a user make with the system, for example, access your patient's vital signs, record their data, visualize them, and similar.

    a). How do you find the functionalities that enabled you as a healthcare professional to see patients' vital signs?

    b). What do you think of the functionalities that enabled you as a healthcare professional to communicate with the patient remotely and send notifications?

    c). How do you find the filtering of patients based on their critical values?

    d). How do you find the possibility to add patients that you want to monitor?

    e). How do you find the possibility to remove patients that you did not want to monitor anymore?

    f). What would you suggest related to these possibilities (add/remove patients from monitoring)?

2. Using data for diagnosis, what is the most suitable method to display the measured vital signs. Graphs and tables as you saw in the sensor-based platform, or do you have other suggestions?

3. Could you please tell me about your experience with the possibility of changing the monitoring interval (the possibility to ask patients to send vital signs more often)?
4. How do you find the real-time possibility of seeing your patient's vital signs?

2.2 Self-descriptiveness

When considering the application of digital technology in the healthcare context, self-descriptiveness is considered as an important parameter. Hence, I would like to understand whether the functionalities you performed with the proposed sensor-based platform were easily understandable and enough self-descriptive.

1. How do you find the utilization of icons for visualizing the functionalities that the system provided?
2. In the proposed sensor-based platform, was the terminology used related to the task (for example, Add Patient button, did it indicated the functionality to add a new patient)?
3. How do you find the arrangement of links and information? Were they arranged in a logical way?
4. Overall, was it easy to understand the functionalities of the system or not?
5. Do you have any suggestions on how we can make the system more self-descriptive?

2.3 Controllability

We need to understand your opinions and feedback on the control over your actions performed with the system. These include system information and possible security leaks for accessing patient's information.

1. How do you find the system information about their progress (for example, after clicking the action buttons, delete/add/edit)?
2. What do you think of the restriction/control, that only authorized healthcare professionals can access patient's information?
3. What do you see as an additional security measure to control unauthorized access to patient information?
4. Do you think there should be other persons that need access to a patient's information (for example caregivers, family members)?
5. Would there be any other scenario that we should consider the security of a patient's information?

2.4 Conformity with user expectations

The proposed sensor-based platform is implemented based on the results of a prior interview study with healthcare professionals of the American Hospital in Kosovo. Nevertheless, we need to confirm if the proposed system complies also with your requirements as a healthcare professional and user of the system.

1. How do you think the proposed sensor-based platform would impact your job performance? Would it enhance it, or cause more difficulties?
2. What do you think about the possibility of having reports with summaries of vital signs for longer periods of time?
   a). How this would affect a patient's treatment?

3. How do you find the navigation through the functionalities that the proposed sensor-based platform offers?
4. Do you find the system's performance fast?
5. How would you evaluate the reliability of the system?
6. Does the system help you accomplish all the tasks that you need for remote monitoring of patients?

2.5 Suitability for learning

Taking into account that users of a system can have various backgrounds and demographic characteristics, the proposed system should always be effortless to learn how to use it. Therefore, I would like to discuss more if the proposed sensor-based platform may be considered as easy to learn and use it.

1. Do you find the proposed sensor-based system, easy to learn?
    a). Would that apply to all levels of users (various backgrounds, educational levels, ages)?
2. Do you think you may need additional training to use this system?
3. How do you find the information grouping into categories or menu items?

3. Additional questions

Finally, I would like to summarize the interview with some general questions related to your opinion and overall feedback on the proposed sensor-based platform.

1. Could you describe a successful implementation of a sensor-based application for chronic disease monitoring in your clinic?
2. What do you see as an advantage of using the proposed sensor-based platform?
    a). If such a system would have been proposed for application, do you intend to use it?
3. What do you see as a challenge for the implementation of the proposed sensor-based platform in your clinic?
    a). How could we overcome these challenges?
4. How do you think the proposed sensor-based platform, may lower treatment costs related to chronic diseases?
    a). What about hospital visits?
    b). Or hospitalization days?
5. Could you please tell me more about your opinion on the impact of the proposed sensor-based platform on a patient's life.
    a). How do you think the proposed sensor-based platform affects a patient's life?

b). How comfortable do you find the application of a remote monitoring platform by patients, considering that they can access their health-related information themselves through their devices?

c). How do you think the usage of the proposed platform by patients, may affect their medical condition?

d). What do you think about the patient's access to their vital signs, would that help them have a better view of their health situation?

e). Do you think that when patients have access to their medical data, this would make your job easier to inform them about their medical condition?

6. Do you think there is also something we did not cover, and that would be of interest?

4. Pilot Study questions

Finally, I would like to ask you some general questions about the interviewing process.

1. How did you find the tasks performed with the system?
   - a). Were they clear?
   - b). Do you think you needed additional information on how to perform the tasks?
   - c). Were all the details of the system covered through the pre-defined tasks?
2. How did you find the interview questions?
   - a). Were they clear?
   - b). Do you think you needed more information on the questions of this interview study?
3. How would you evaluate the interviewing process?
   - a). Did it take too long?
   - b). Was it clear and structured?
   - c). Is there something that you would suggest to us for consideration in other interviews?

I would like to thank you again for being part of this investigation. I appreciate your time and willingness to take part.

Appendix B.8 Study 2, Tasks that were performed with the SBNHealth

South-East European Research Centre (SEERC) - University of Sheffield
Information School
Address: SEERC, 24 Proxenou Koromila Street, 54622, Thessaloniki, Greece
Contact: abasholli1@sheffield.ac.uk, adbasholli@seerc.org, 00383 45 398 775

Tasks to be performed with the system*

Task number	Description of the task
1	Create a new user account that will allow you to access the web platform
	1. In your browser enter the following link: 2. On the top-right side of the web page, click the Sign-up button 3. Fill in all the required information 4. Click the Sign-up button at the bottom of the dialogue box
2	Log in with the created account
3	Register a patient to monitor
	1. From the left menu, select New Patient 2. You will get a random-generated code (unique code of a patient) from the Android app. The patient will add you as authorized medical personnel to view his/her medical information 3. Enter the random-generated code 4. Set the critical range of values for the specific patient
4	Access patient's data
	1. Write patient's random code 2. Access all the records of his/her vital signs, either in table format or as a graph
5	View all your patients' vital signs
	1. From the left menu, select All Patients
6	Change the transmission mode of a patient's vital signs
	1. From the left menu, select All Patients 2. In the table of patients, select one of the transmission modes available for each patient (buttons at the end of each table row)
7	Get patient's real-time data

	1. From the left menu, select All Patients 2. In the table of patients, select one of the All the time transmission mode 3. Wait until the patient receives a notification to confirm that he/she is allowing you to access the vital signs in real-time 4. In case the patient accepts to be monitored in real-time, you will receive an email notifying you of this 5. In the table of Real-Time patients, you can have the list of all patients that confirmed to be monitored in Real-time 6. Select the Show button at the end of each table-row, to view in real-time the patient vital signs
8	Contact a critical patient
	1. From the left menu, select Home 2. In case there are patients whose vital signs are not within the normal range of values, they will appear in a table, in this page 3. You can write an email or contact through phone each one of them
9	Edit your account details
	1. Hover over the top-right user avatar 2. Select the Account Details from the dropdown list 3. Edit any information that you want 4. Select Save button
10	Logout from the system
	1. Hover over the top-right user avatar 2. Select the Logout from the dropdown list

* This document will be translated also in the Albanian language, as the native language of participants

Appendix B.9 Study 2, Interview questions categorized according to technology acceptance variables

Category	Question	Additional questions	Variable (TAM model)
1. Setting the interview context	2. Could you please tell me more about your overall experience with the sensor-based platform, that you already performed some tasks with.	a). How would you describe a typical working scenario with this sensor-based platform?	Job relevance (TAM2)
		b). Have you used any similar system before? If yes, how would you compare the system you used before with the proposed sensor-based platform?	
	3. Could you please tell me more about the application of the proposed sensor-based platform?	a). How do you find the application of the proposed sensor-based platform in your clinic? Would your colleagues support and use it?	Subjective norm (TAM2)
		b). How do find the application of the proposed sensor-based platform in every healthcare institution in our country, considering Kosovo as a developing country? Would other healthcare professionals apply it?	Subjective norm (TAM2)
		c). How do you think the application of the proposed sensor-based platform would affect your working schedule?	Job relevance (TAM2)
		d). How do you think the application of the proposed sensor-based platform would affect your workload?	Job relevance (TAM2)
		e). How do you think the application of the proposed sensor-based platform would affect the prescriptions of the therapies, for remote monitoring patients?	Job relevance (TAM2)
		f). Overall, how do you think the application of the proposed sensor-based platform would affect the healthcare systems of developing countries.	Perceived usefulness (TAM2)

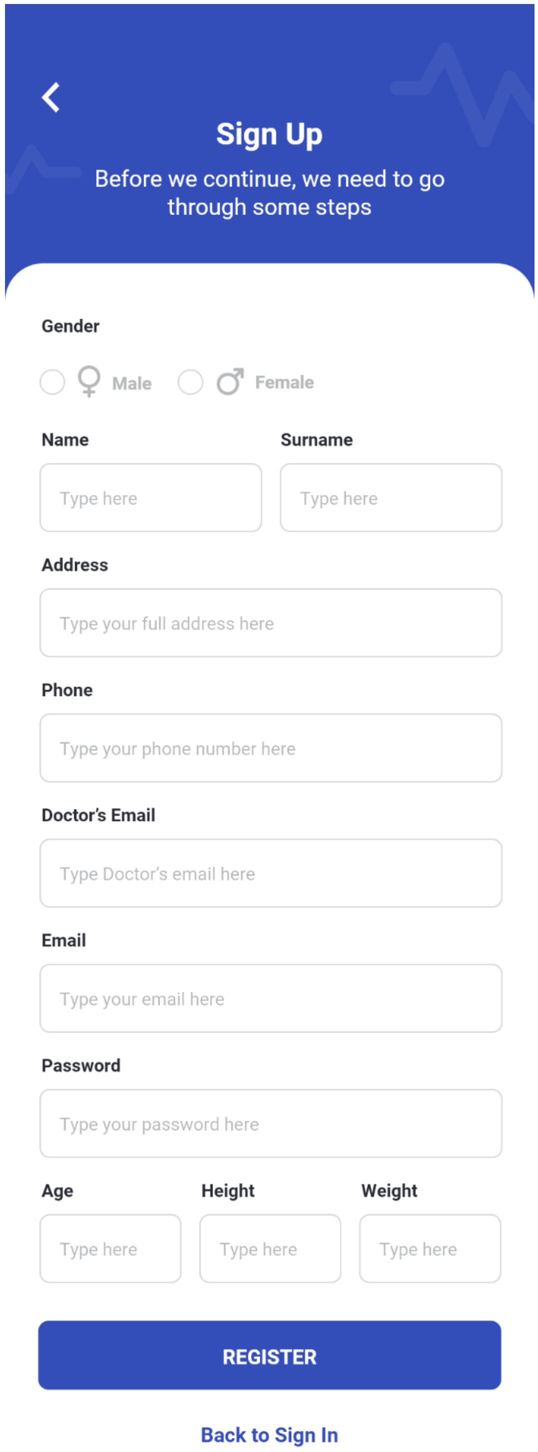
2. Suitability for the task	1. Could you please tell me more about the functionalities that are relevant to fulfil a task? Tasks include actions that you as a user make with the system, for example, access your patient's vital signs, record their data, visualize them, and similar.	a). How do you find the functionalities that enabled you as a healthcare professional to see patients' vital signs?	Perceived usefulness (TAM2)
		b). What do you think of the functionalities that enabled you as a healthcare professional to communicate with the patient remotely and send notifications?	Perceived usefulness (TAM2)
		c). How do you find the filtering of patients based on their critical values?	Perceived usefulness (TAM2)
		d). How do you find the possibility to add patients that you want to monitor?	Perceived ease of use (TAM2)
		e). How do you find the possibility to remove patients that you did not want to monitor anymore?	Perceived ease of use (TAM2)
		f). What would you suggest related to these possibilities (add/remove patients from monitoring)?	Perceived ease of use (TAM2)
	2. Using data for diagnosis, what is the most suitable method to display the measured vital signs. Graphs and tables as you saw in the sensor-based platform, or you have other suggestions?		Perceived usefulness (TAM2)
	3. Could you please tell me about your experience with the possibility of changing the monitoring interval (the possibility to ask patients to send vital signs more often)?		Perceived usefulness (TAM2)
	4. How do you find the real-time possibility of seeing your patient's vital signs?		Job relevance (TAM2)
3. Self-descriptiveness	1. How do you find the utilization of icons for visualizing the functionalities that the system provided?		Perceived ease of use (TAM2)
	2. In the proposed sensor-based platform, was the terminology used related to the task (for example, Add Patient button, did it		Task-Technology Fit (TTF)

	indicated the functionality to add a new patient)?		
	3. How do you find the arrangement of links and information? Where they arranged in a logical way?		Task-Technology Fit (TTF)
	4. Overall, was it easy to understand the functionalities of the system or not?		Perceived ease of use (TAM2)
	5. Do you have any suggestions on how we can make the system more self-descriptive?		Perceived ease of use (TAM2)
4. Controllability	1. How do you find the system information about its progress (for example, after clicking the action buttons, delete/add/edit)?		Performance expectancy (UTAUT model)
	2. What do you think of the restriction/control, that only authorized healthcare professionals can access patient's information?		Task-Technology Fit (TTF)
	3. What do you see as an additional security measure to control unauthorized access to patient information?		Task-Technology Fit (TTF)
	4. Do you think there should be other persons that need access to patient's information (for example caregivers, family members)?		Task-Technology Fit (TTF)
	5. Would there be any other scenario that we should consider the security of patient's information?		Task-Technology Fit (TTF)
5. Conformity with user expectations	1. How do you think the proposed sensor-based platform would impact your job performance? Would it enhance it, or cause more difficulties?		Job relevance (TAM2)
	2. What do you think about the possibility of having reports with summaries of vital signs for longer periods of time?	a). How this would affect patient's treatment?	Social influence (UTAUT model)

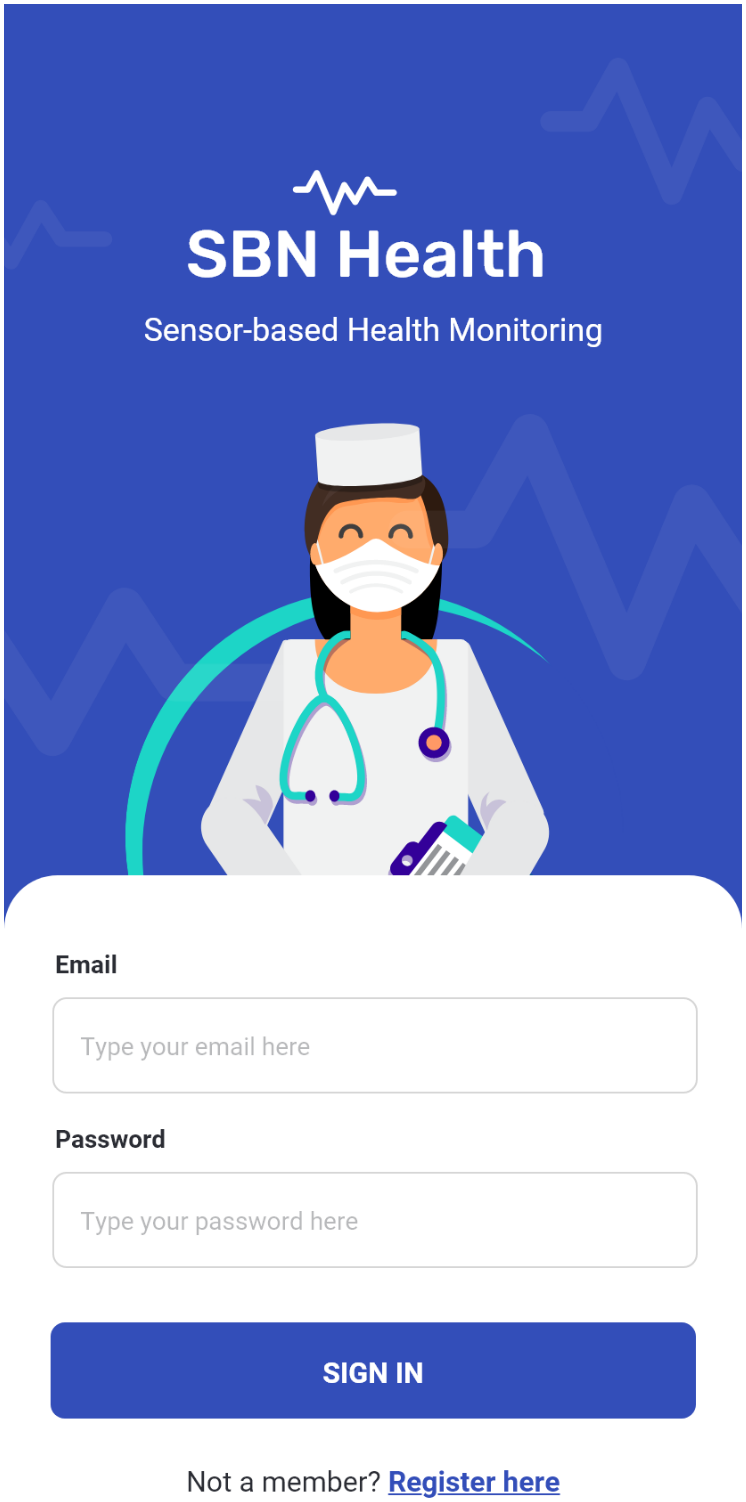
	3. How do you find the navigation through the functionalities that the proposed sensor-based platform offers?		Performance expectancy (UTAUT model)
	4. Do you find the system's performance fast?		Performance expectancy (UTAUT model)
	5. How would you evaluate the reliability of the system?		Perceived usefulness (TAM2)
	6. Does the system help you accomplish all the tasks that you need for remote monitoring of patients?		Perceived usefulness (TAM2)
6. Suitability for learning	1. Do you find the proposed sensor-based system, easy to learn?	a). Would that apply to all levels of users (various backgrounds, educational levels, ages)?	Perceived ease of use (TAM2)
	2. Do you think you may need additional training to use this system?		Perceived ease of use (TAM2)
	3. How do you find the information grouping into categories or menu items		Perceived ease of use (TAM2)
7. Additional questions	1. Could you describe a successful implementation of a sensor-based application for chronic disease monitoring in your clinic?		Behavioral Intention (TAM2)
	2. What do you see as an advantage of using the proposed sensor-based platform?	a). If such a system would have been proposed for application, do you intent to use it?	Behavioral Intention (TAM2)
	3. What do you see as a challenge for the implementation of the proposed sensor-based platform in your clinic?	a). How could we overcome these challenges?	Perceived usefullness (TAM 2)
	4. How do you think the proposed sensor-based platform, may lower treatment costs related to chronic diseases?	a). What about hospital visits?	Perceived usefullness (TAM 2)
		b). Or hospitalization days?	Perceived usefulness (TAM 2)
		a). How do you think the proposed sensor-based platform affects a patient's life?	Perceived usefullness (TAM 2)

	5. Could you please tell me more about your opinion on the impact of the proposed sensor-based platform in a patient's life.	b). How comfortable do you find the application of a remote monitoring platform by patients, considering that they can access their health-related information themselves through their devices?	Truth-telling (First Interview Study variable, chapter 5)
		c). How do you think the usage of the proposed platform by patients, may affect their medical condition?	Truth-telling (First Interview Study variable, chapter 5)
		d). What do you think about the patient's access to their vital signs, would that help them have a better view of their health situation?	Truth-telling (First Interview Study variable, chapter 5)
		e). Do you think that when patients will have access to their medical data, this would make your job easier to inform them about their medical condition?	Truth-telling (First Interview Study variable, chapter 5)

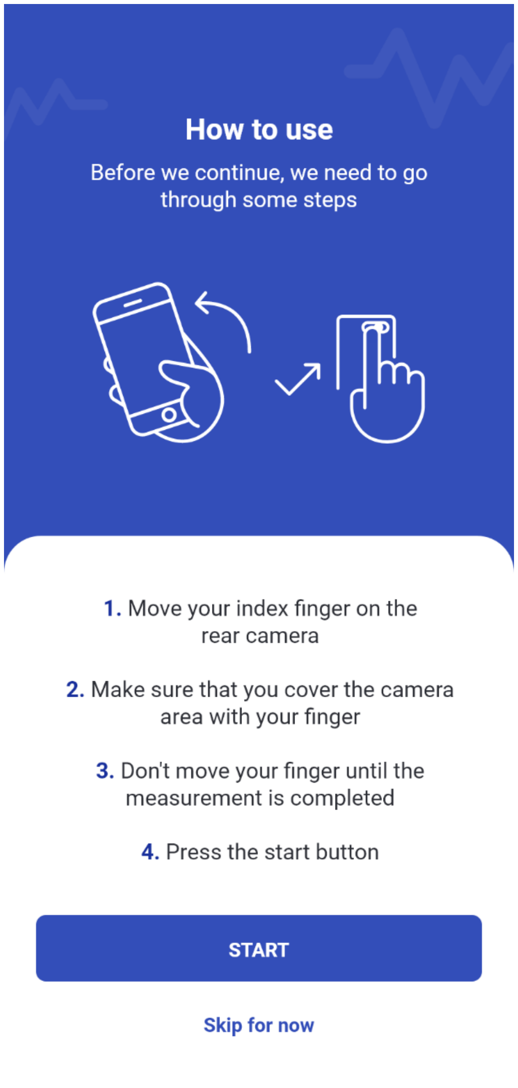
Appendix C.1 Mobile app GUI, Account registration



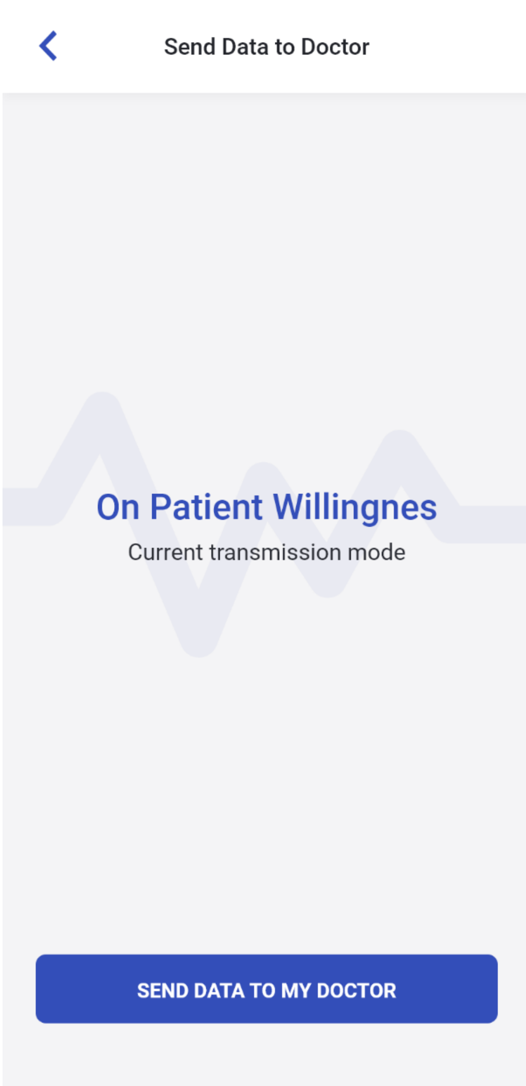
Appendix C.2 Mobile app GUI, Patient login



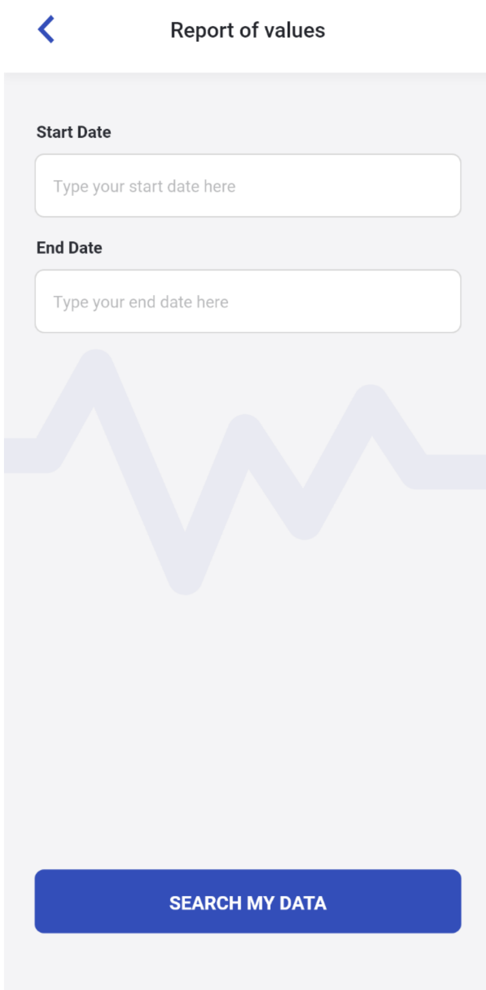
Appendix C.3 Mobile app GUI, Measuring vital signs

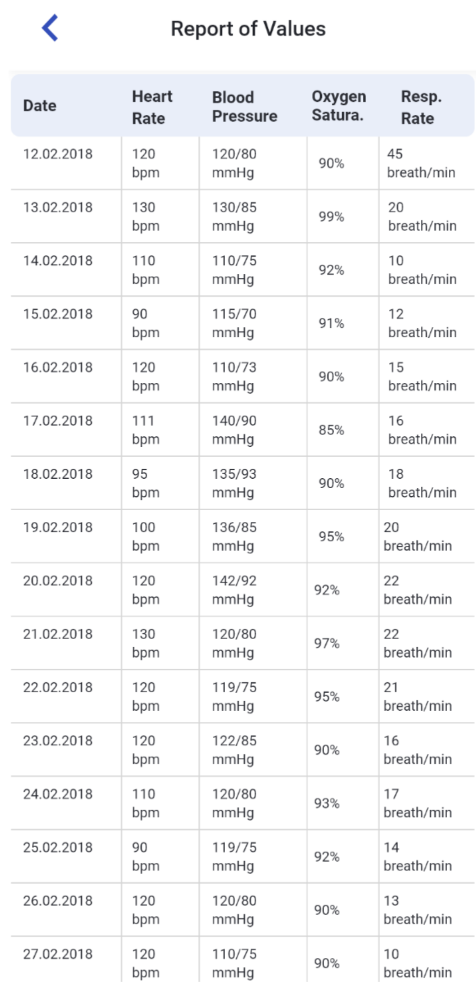


Appendix C.4 Mobile app GUI, Send data to the monitoring staff



Appendix C.5 Mobile app GUI, Generate a report of values





Date	Heart Rate	Blood Pressure	Oxygen Satura.	Resp. Rate
12.02.2018	120 bpm	120/80 mmHg	90%	45 breath/min
13.02.2018	130 bpm	130/85 mmHg	99%	20 breath/min
14.02.2018	110 bpm	110/75 mmHg	92%	10 breath/min
15.02.2018	90 bpm	115/70 mmHg	91%	12 breath/min
16.02.2018	120 bpm	110/73 mmHg	90%	15 breath/min
17.02.2018	111 bpm	140/90 mmHg	85%	16 breath/min
18.02.2018	95 bpm	135/93 mmHg	90%	18 breath/min
19.02.2018	100 bpm	136/85 mmHg	95%	20 breath/min
20.02.2018	120 bpm	142/92 mmHg	92%	22 breath/min
21.02.2018	130 bpm	120/80 mmHg	97%	22 breath/min
22.02.2018	120 bpm	119/75 mmHg	95%	21 breath/min
23.02.2018	120 bpm	122/85 mmHg	90%	16 breath/min
24.02.2018	110 bpm	120/80 mmHg	93%	17 breath/min
25.02.2018	90 bpm	119/75 mmHg	92%	14 breath/min
26.02.2018	120 bpm	120/80 mmHg	90%	13 breath/min
27.02.2018	120 bpm	110/75 mmHg	90%	10 breath/min

Appendix C.6 Mobile app GUI, Add monitoring medical staff

Appendix C.7 Patient monitoring request

Gmail

Adelina Basholli <adelina.basholli@gmail.com>

Patient Monitoring Request

healthsbn@gmail.com <healthsbn@gmail.com> Mon, Jan 25, 2021 at 2:20 PM
To: adelina.basholli@gmail.com

Patient Adelina, with email: adbasholli@seerc.org
is requesting your supervision of his/her health parameters.
This means that you will have access to these data and provide feedback to the patient.

If you wish to monitor the patient remotely, please login with your account to the below link and enter patient's respective code: 422605-DXKZ8

www.sbnhealth.com

This email was send automatically on patient registration in our mobile app.

Appendix C.8 Vital signs transmission mode change

Gmail

Adelina Basholli <adelina.basholli@gmail.com>

Patient's Transmission Mode of the Vital Signs Changed!

healthsbn@gmail.com <healthsbn@gmail.com>
To: adelina.basholli@gmail.com

Mon, Jan 25, 2021 at 2:31 PM

Patient with the following details:

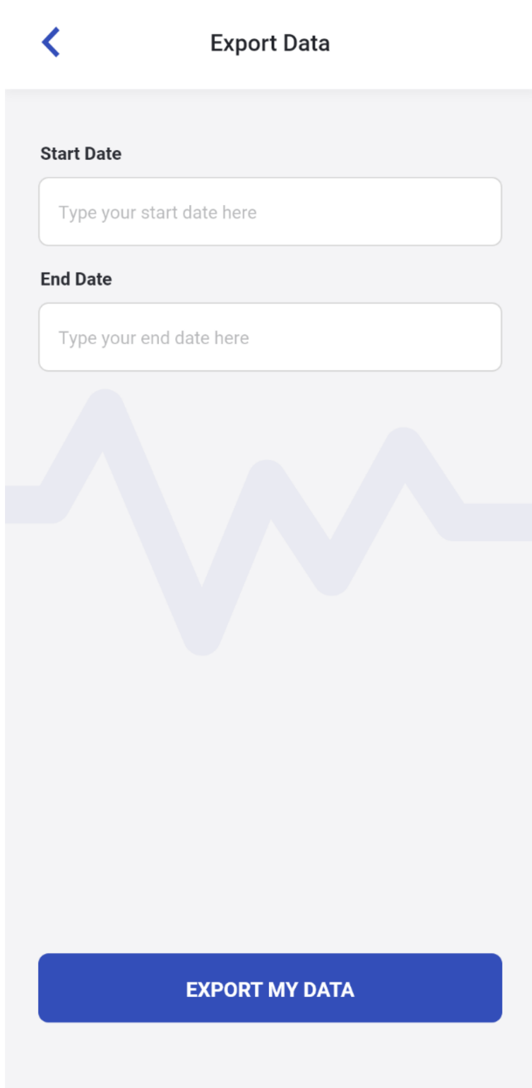
Adelina Basholli, adbasholli@seerc.org

has changed her transmission mode of the vital signs to: Real Time Transmission

You can login to www.sbnhealth.com and see this patient's vital signs.

This email was send automatically on patient monitoring vital signs from the mobile app.

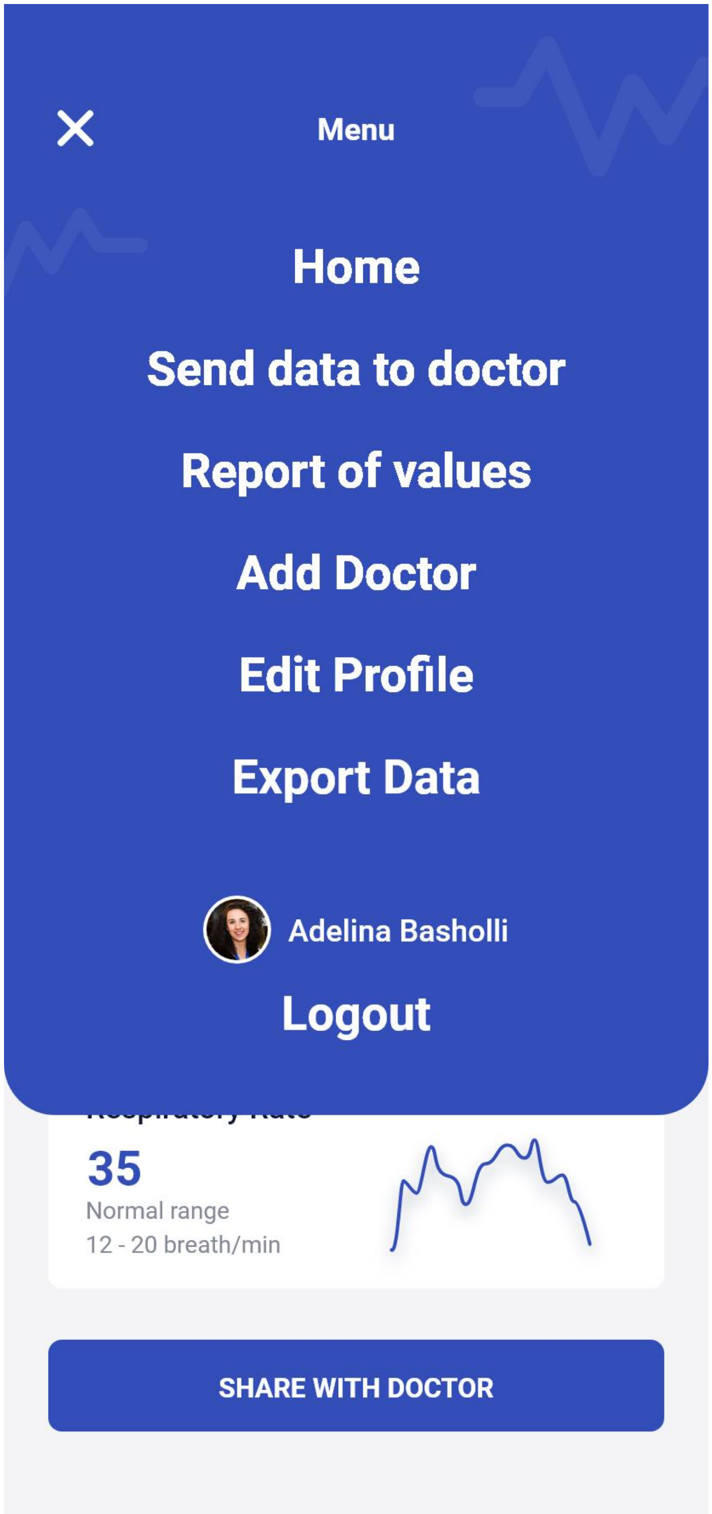
Appendix C.9 Mobile app GUI, Export vital signs in .pdf file



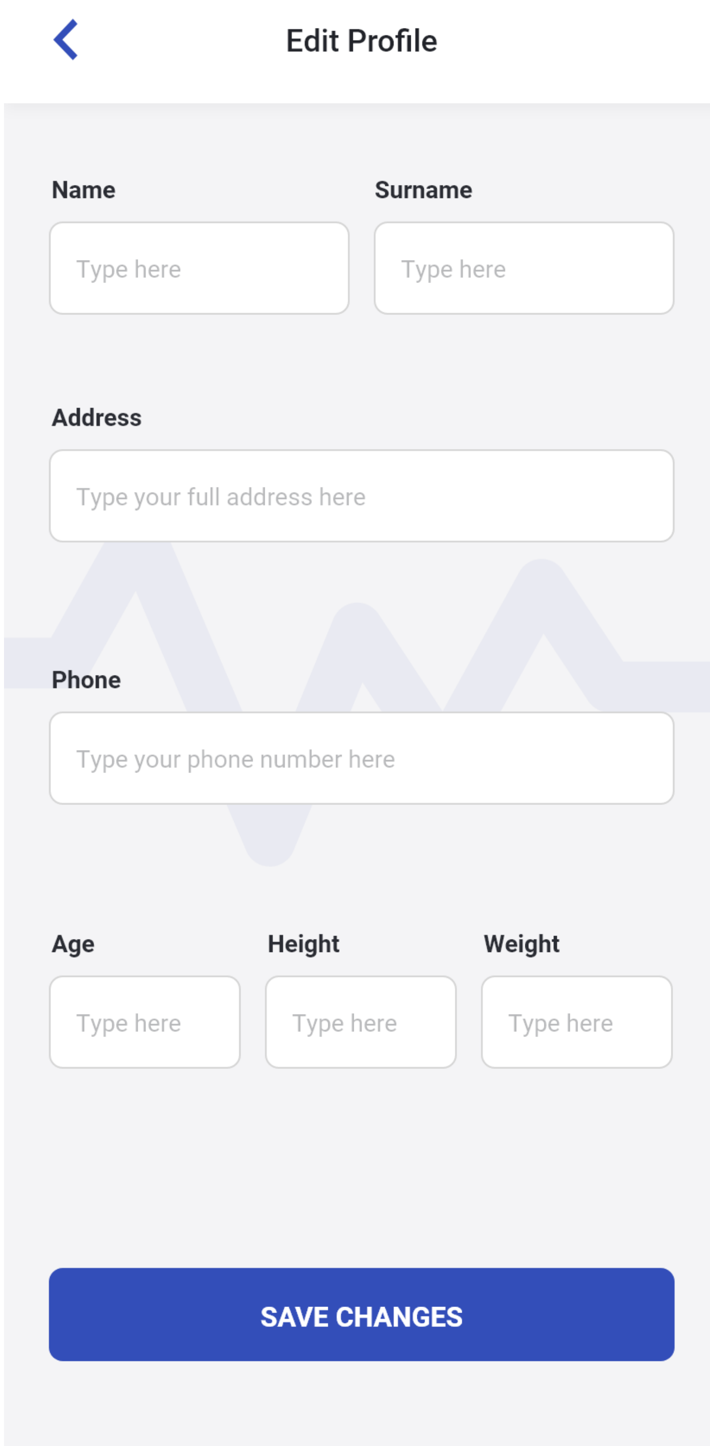
Report of values for Adelina Basholli
From: 12.02.2018 To: 01.03.2018

Date	Heart Rate	Blood Pressure	Oxygen Satura.	Resp. Rate
12.02.2018	120 bpm	120/80 mmHg	90%	45 breath/min
13.02.2018	130 bpm	130/85 mmHg	99%	20 breath/min
14.02.2018	110 bpm	110/75 mmHg	92%	10 breath/min
15.02.2018	90 bpm	115/70 mmHg	91%	12 breath/min
16.02.2018	120 bpm	110/73 mmHg	90%	15 breath/min
17.02.2018	111 bpm	140/90 mmHg	85%	16 breath/min
18.02.2018	95 bpm	135/93 mmHg	90%	18 breath/min
19.02.2018	100 bpm	136/85 mmHg	95%	20 breath/min
20.02.2018	120 bpm	142/92 mmHg	92%	22 breath/min
21.02.2018	130 bpm	120/80 mmHg	97%	22 breath/min
22.02.2018	120 bpm	119/75 mmHg	95%	21 breath/min
23.02.2018	120 bpm	122/85 mmHg	90%	16 breath/min
24.02.2018	110 bpm	120/80 mmHg	93%	17 breath/min
25.02.2018	90 bpm	119/75 mmHg	92%	14 breath/min
26.02.2018	120 bpm	120/80 mmHg	90%	13 breath/min
27.02.2018	120 bpm	110/75 mmHg	90%	10 breath/min

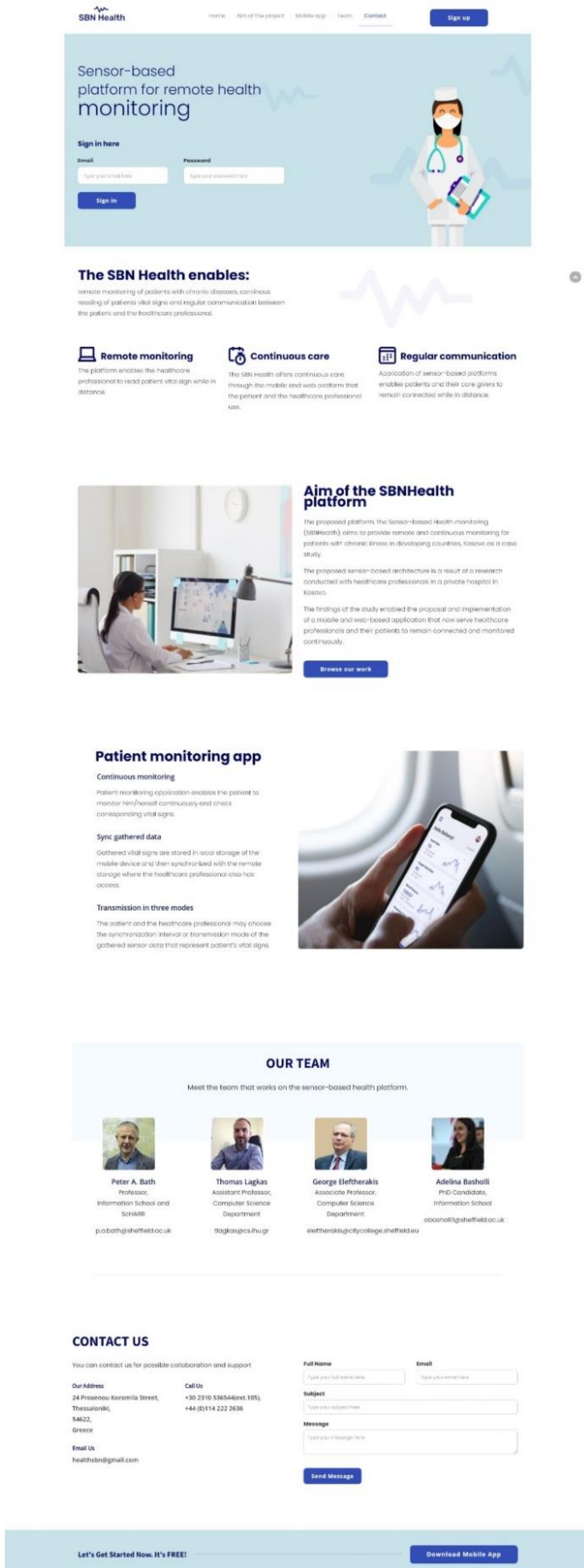
Appendix C.10 Mobile app GUI, Left menu



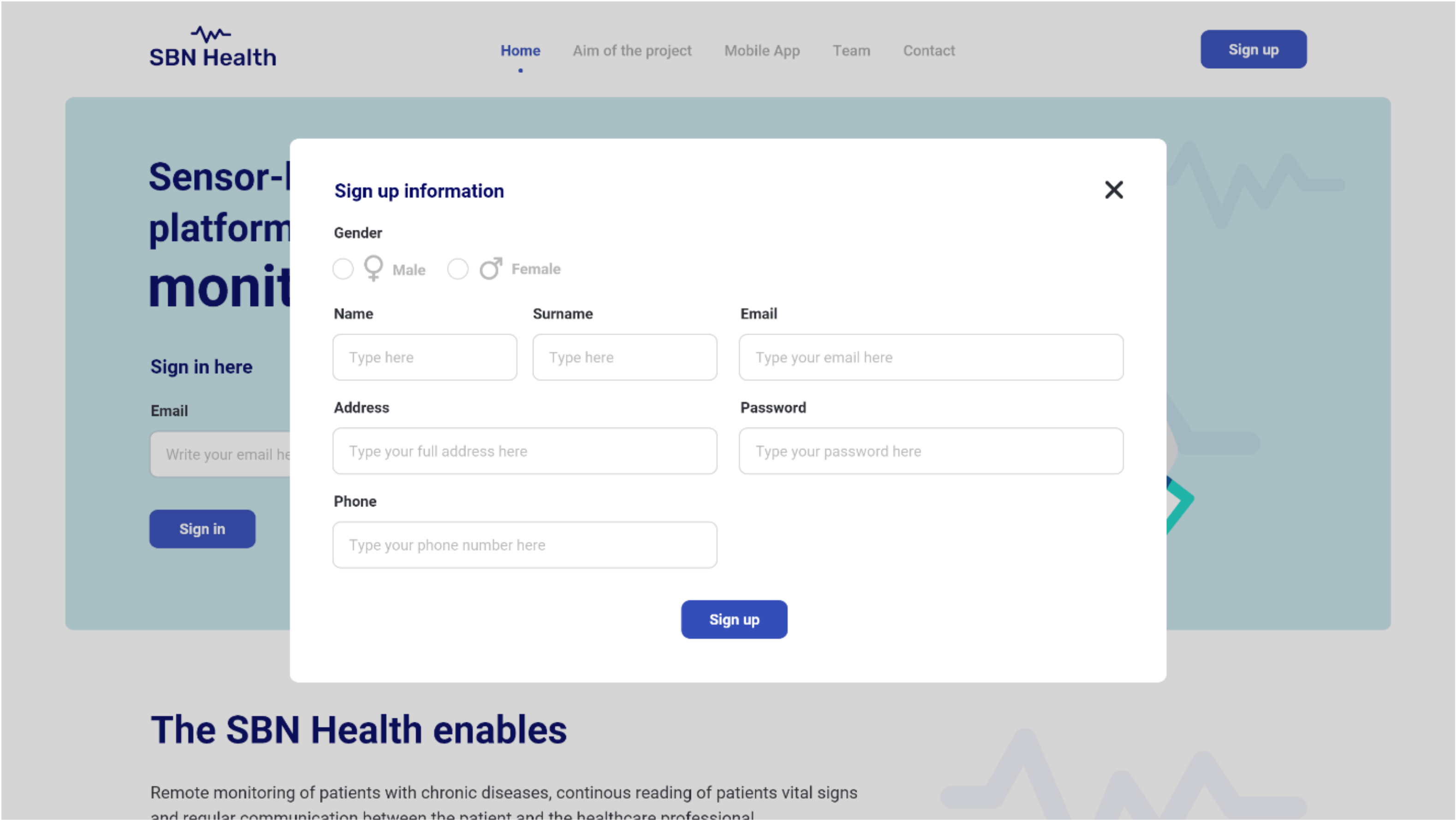
Appendix C.11 Mobile app GUI, Edit profile of a patient



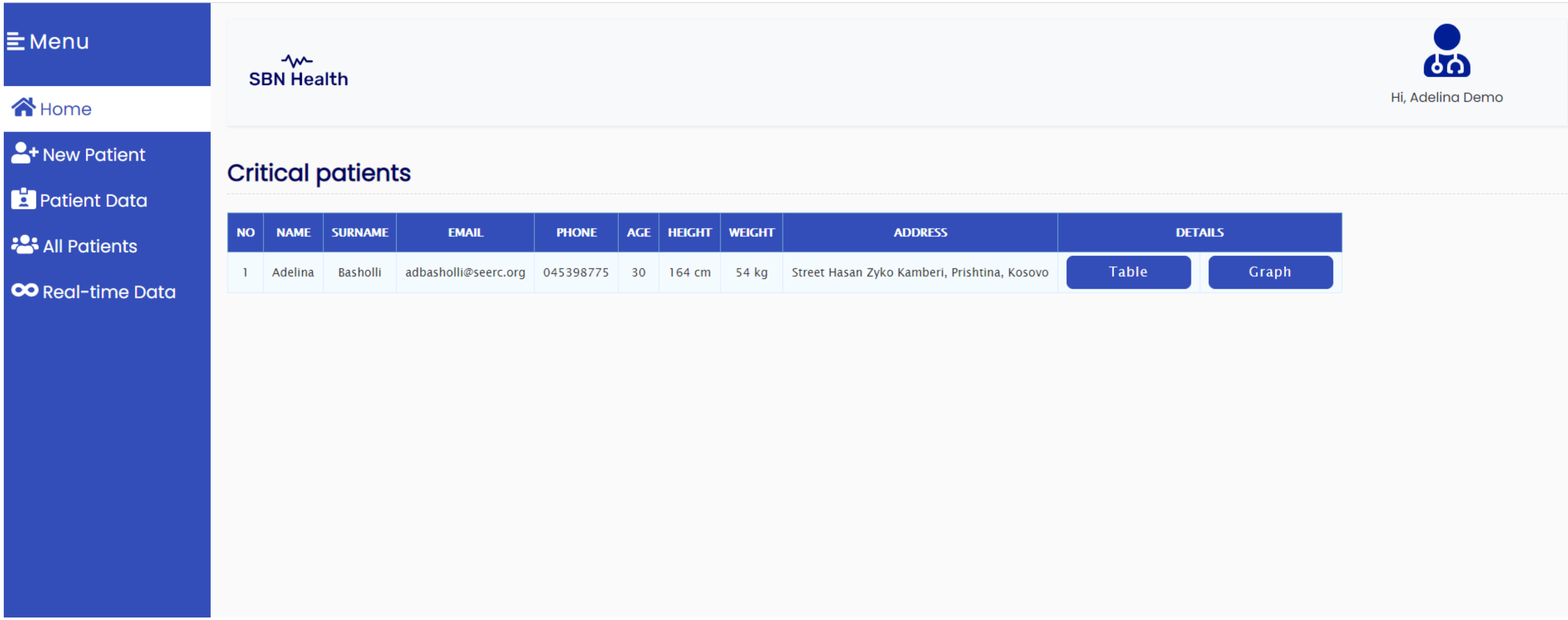
Appendix D.1 Web app GUI, Landing page



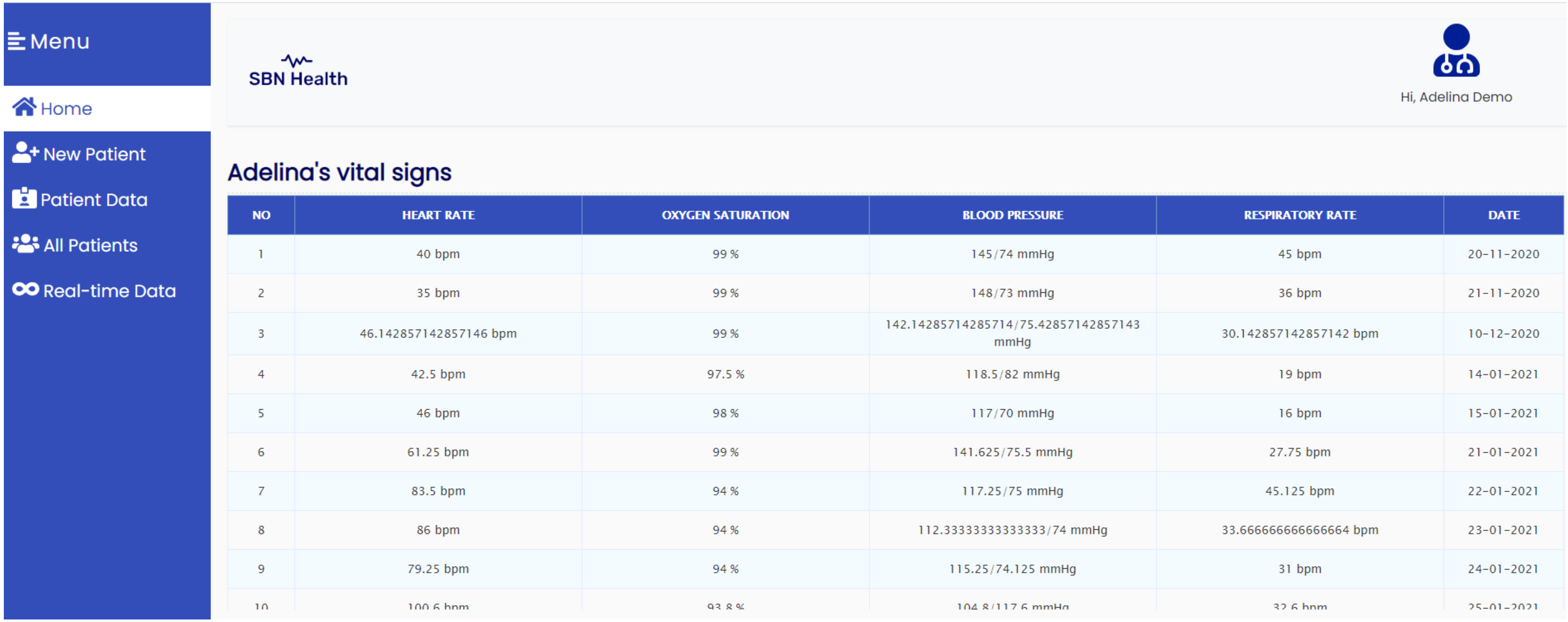
Appendix D.2 Web app GUI, Account registration



Appendix D.3 Web app GUI, List of critical patients

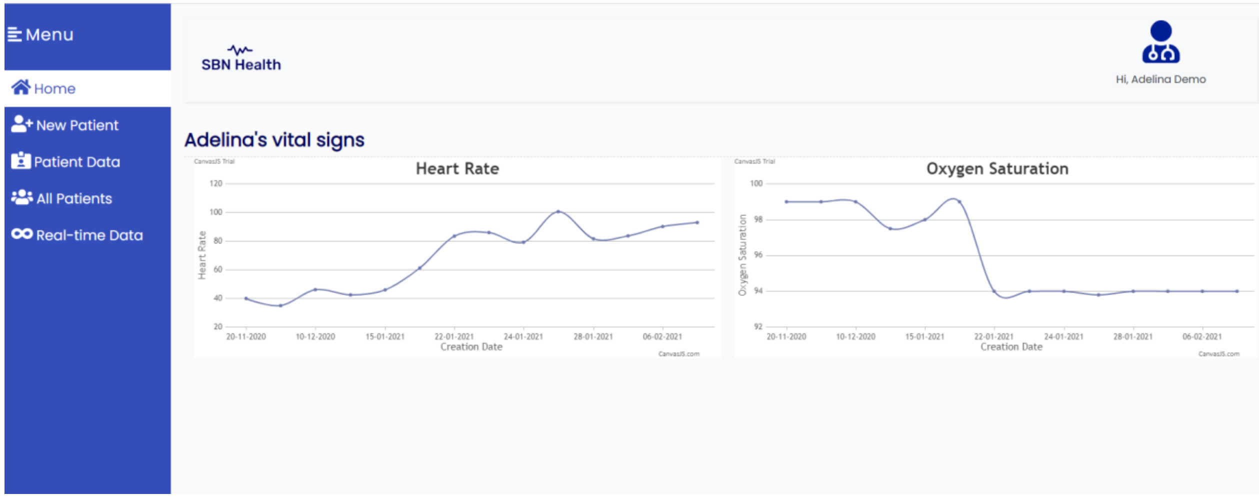


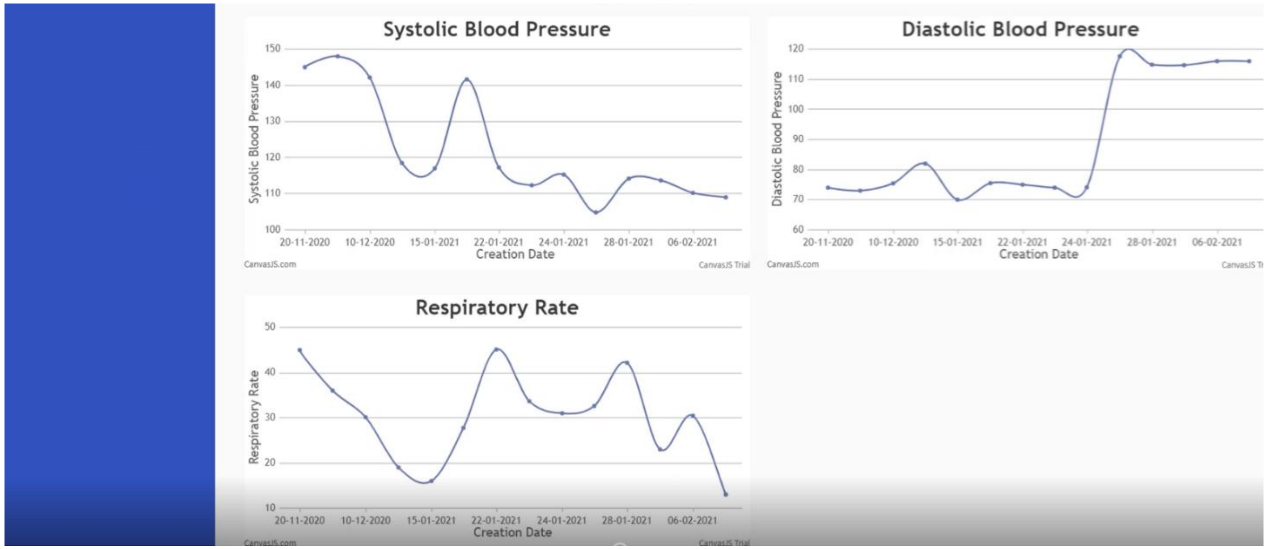
Appendix D.4 Web app GUI, A critical patient's vital signs, table view



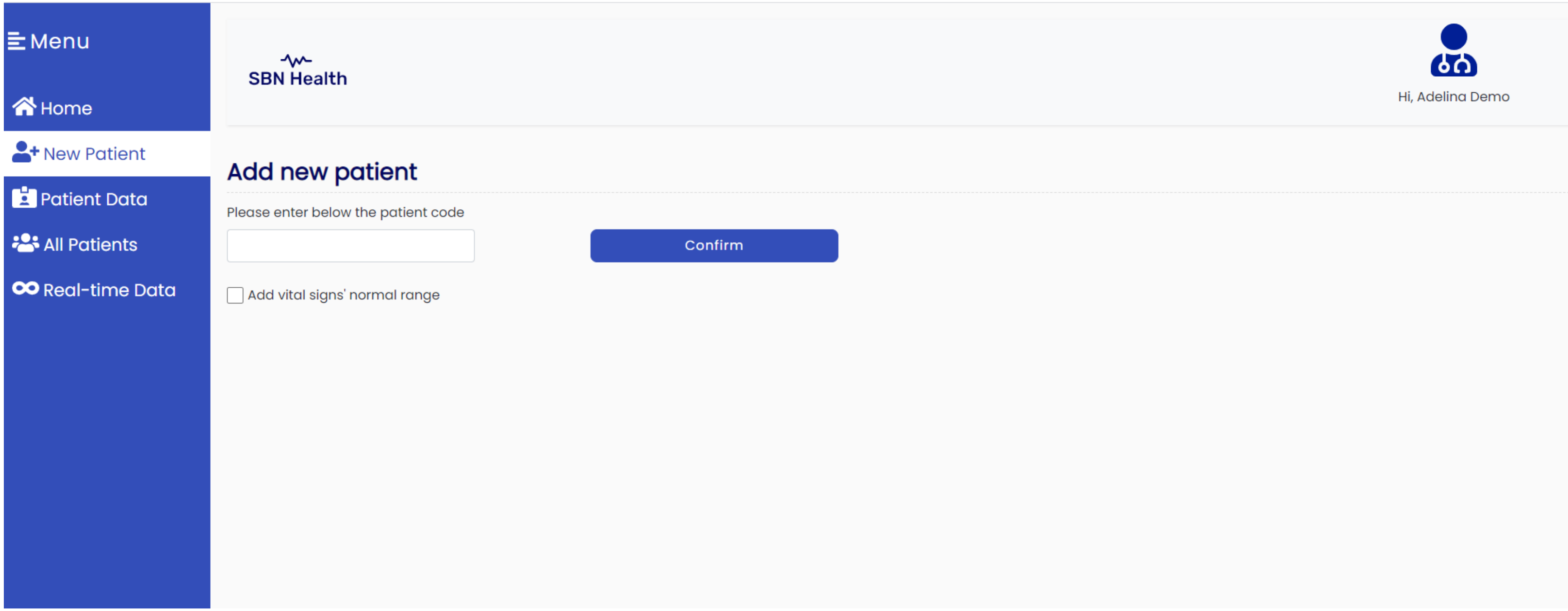
NO	HEART RATE	OXYGEN SATURATION	BLOOD PRESSURE	RESPIRATORY RATE	DATE
1	40 bpm	99 %	145/74 mmHg	45 bpm	20-11-2020
2	35 bpm	99 %	148/73 mmHg	36 bpm	21-11-2020
3	46.142857142857146 bpm	99 %	142.14285714285714/75.42857142857143 mmHg	30.142857142857142 bpm	10-12-2020
4	42.5 bpm	97.5 %	118.5/82 mmHg	19 bpm	14-01-2021
5	46 bpm	98 %	117/70 mmHg	16 bpm	15-01-2021
6	61.25 bpm	99 %	141.625/75.5 mmHg	27.75 bpm	21-01-2021
7	83.5 bpm	94 %	117.25/75 mmHg	45.125 bpm	22-01-2021
8	86 bpm	94 %	112.33333333333333/74 mmHg	33.666666666666664 bpm	23-01-2021
9	79.25 bpm	94 %	115.25/74.125 mmHg	31 bpm	24-01-2021
10	100.6 bpm	93.8 %	104.8/117.6 mmHg	32.6 bpm	25-01-2021

Appendix D.5 Web app GUI, A critical patient's vital signs, graph view

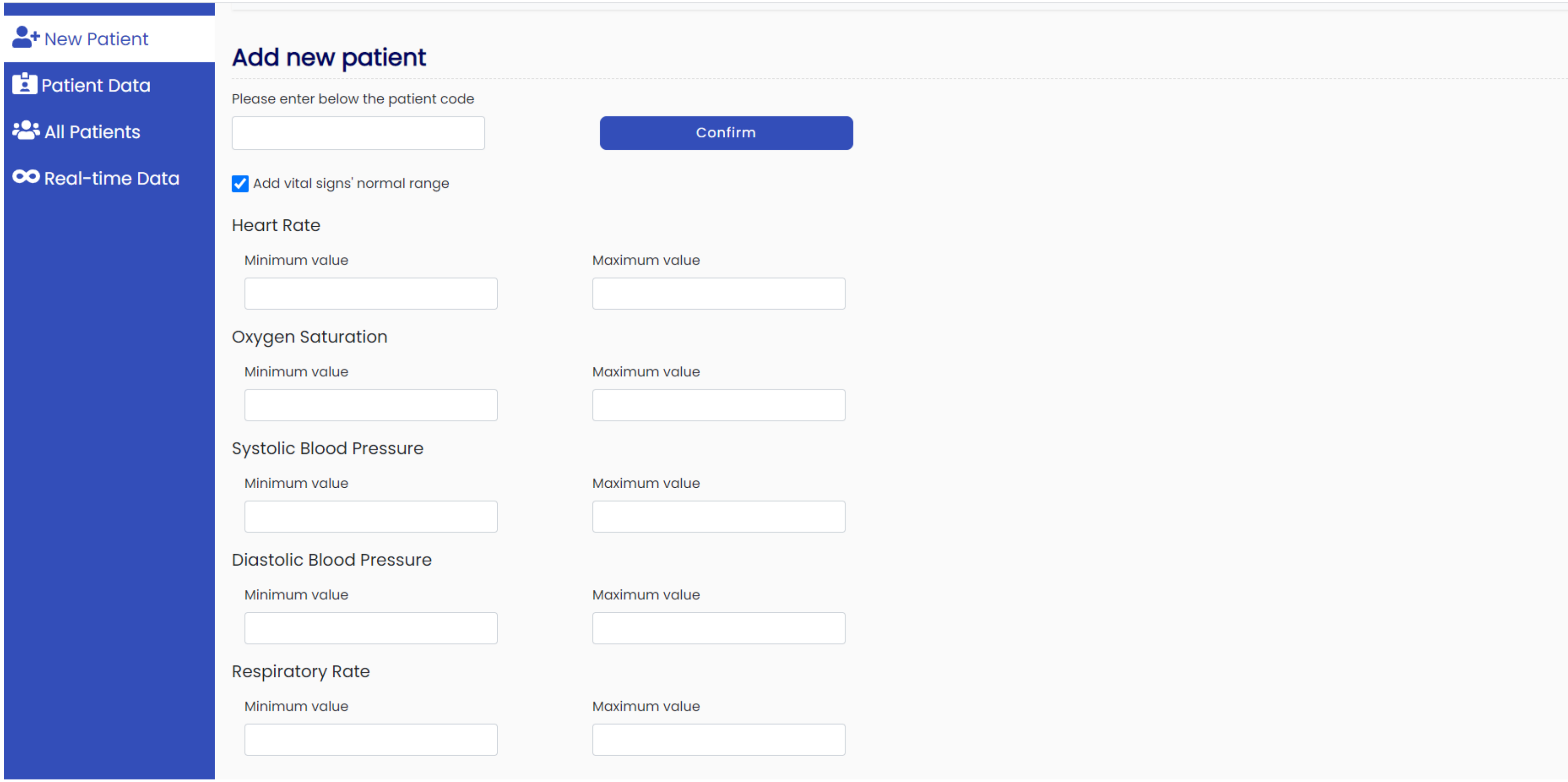




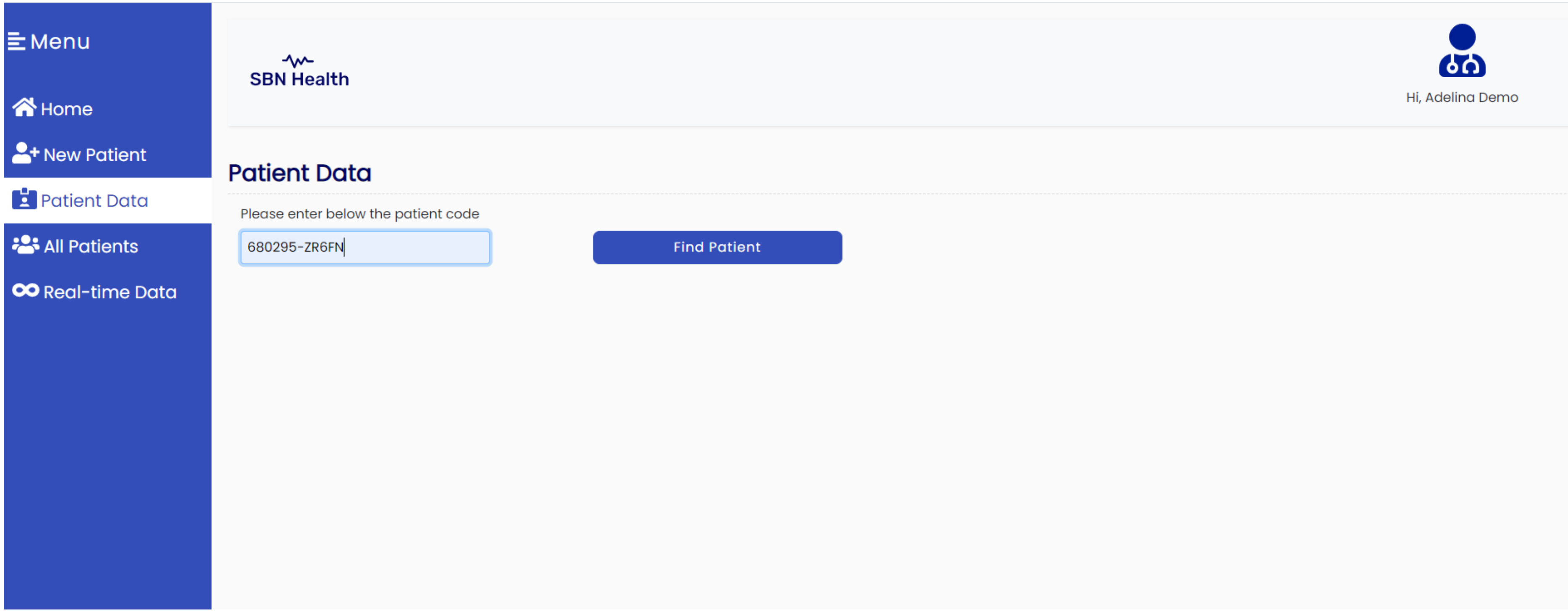
Appendix D.6 Web app GUI, Add new patient for monitoring

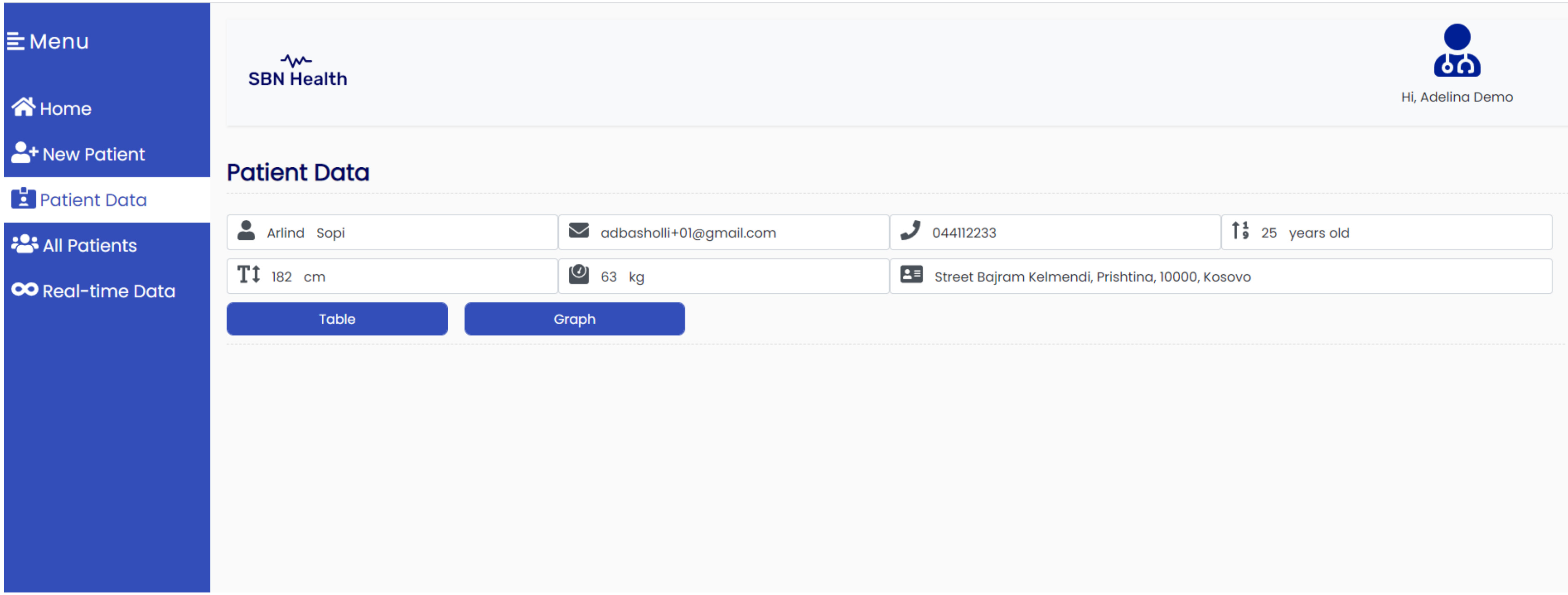


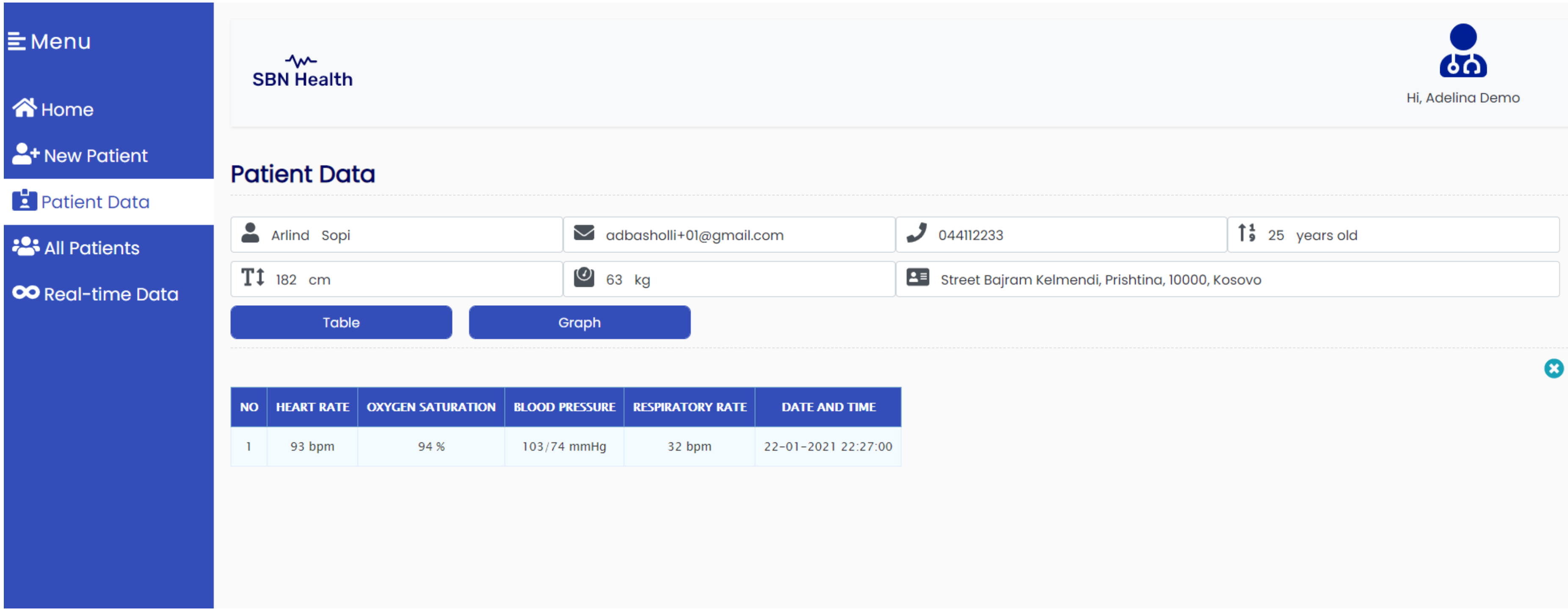
Appendix D.7 Web app GUI, Add the normal range of values for a specific patient

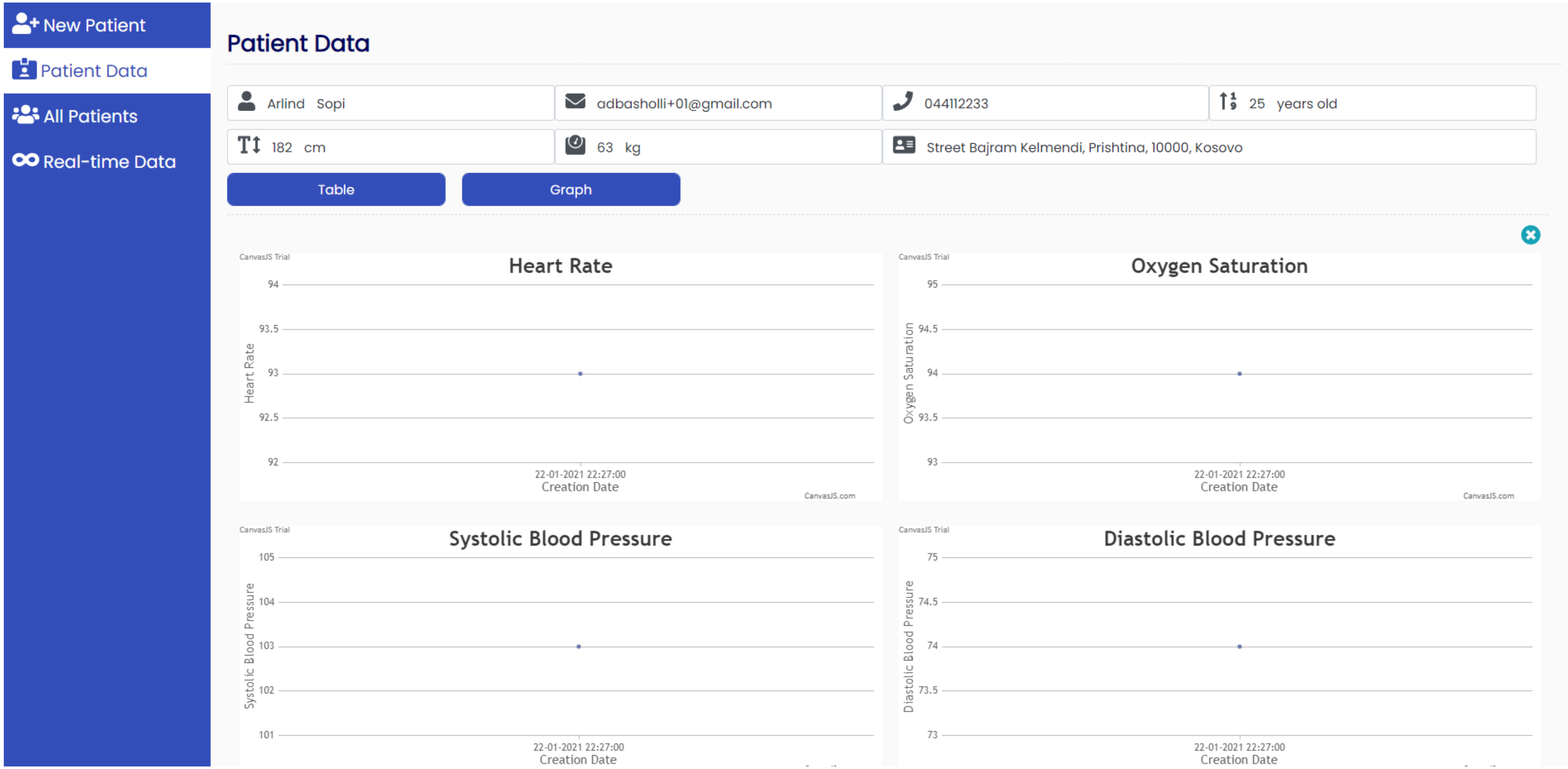


Appendix D.8 Web app GUI, Access patient data by the code



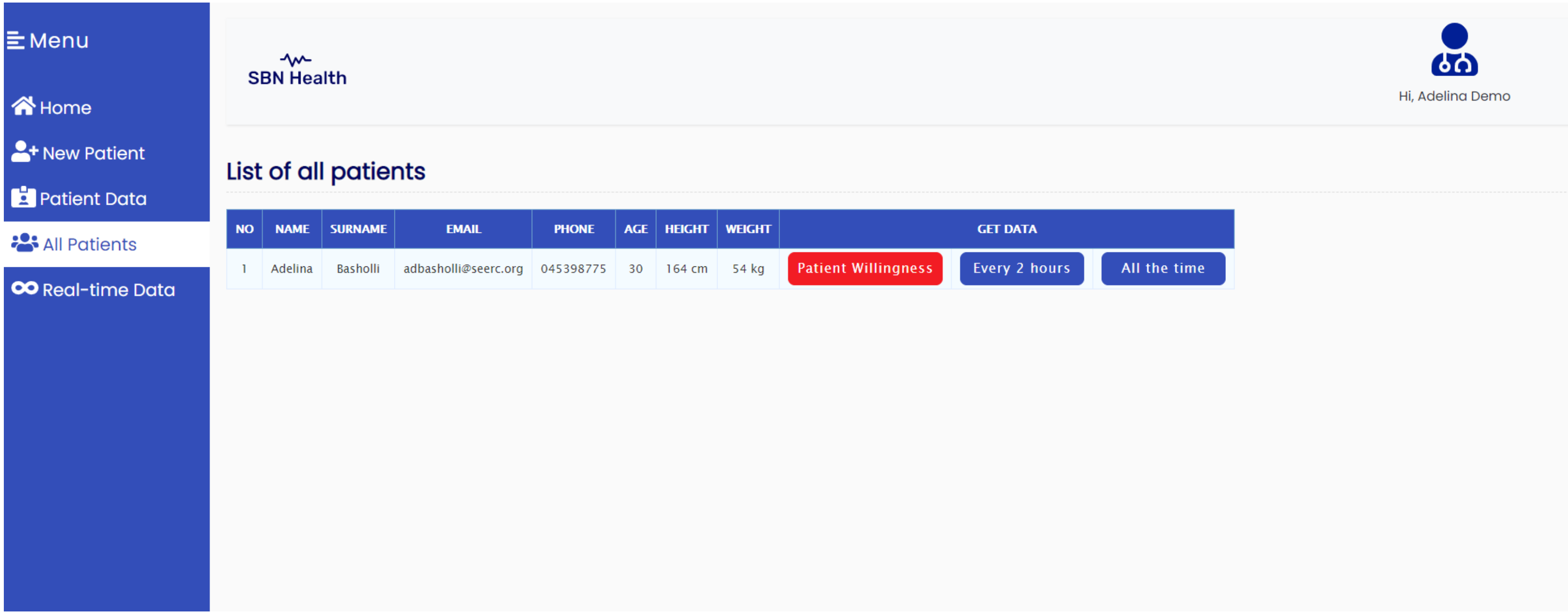

Menu
Home
New Patient
Patient Data
All Patients
Real-time Data
SBN Health
Hi, Adelina Demo
Patient Data
Arlind Sopi
adbasholli+01@gmail.com
044112233
25 years old
182 cm
63 kg
Street Bajram Kelmendi, Prishtina, 10000, Kosovo
Table
Graph


Menu
Home
New Patient
Patient Data
All Patients
Real-time Data
SBN Health
Hi, Adelina Demo
Patient Data
Arlind Sopi
adbasholli+01@gmail.com
044112233
25 years old
182 cm
63 kg
Street Bajram Kelmendi, Prishtina, 10000, Kosovo
Table
Graph
NO | HEART RATE | OXYGEN SATURATION | BLOOD PRESSURE | RESPIRATORY RATE | DATE AND TIME
1 | 93 bpm | 94 % | 103/74 mmHg | 32 bpm | 22-01-2021 22:27:00

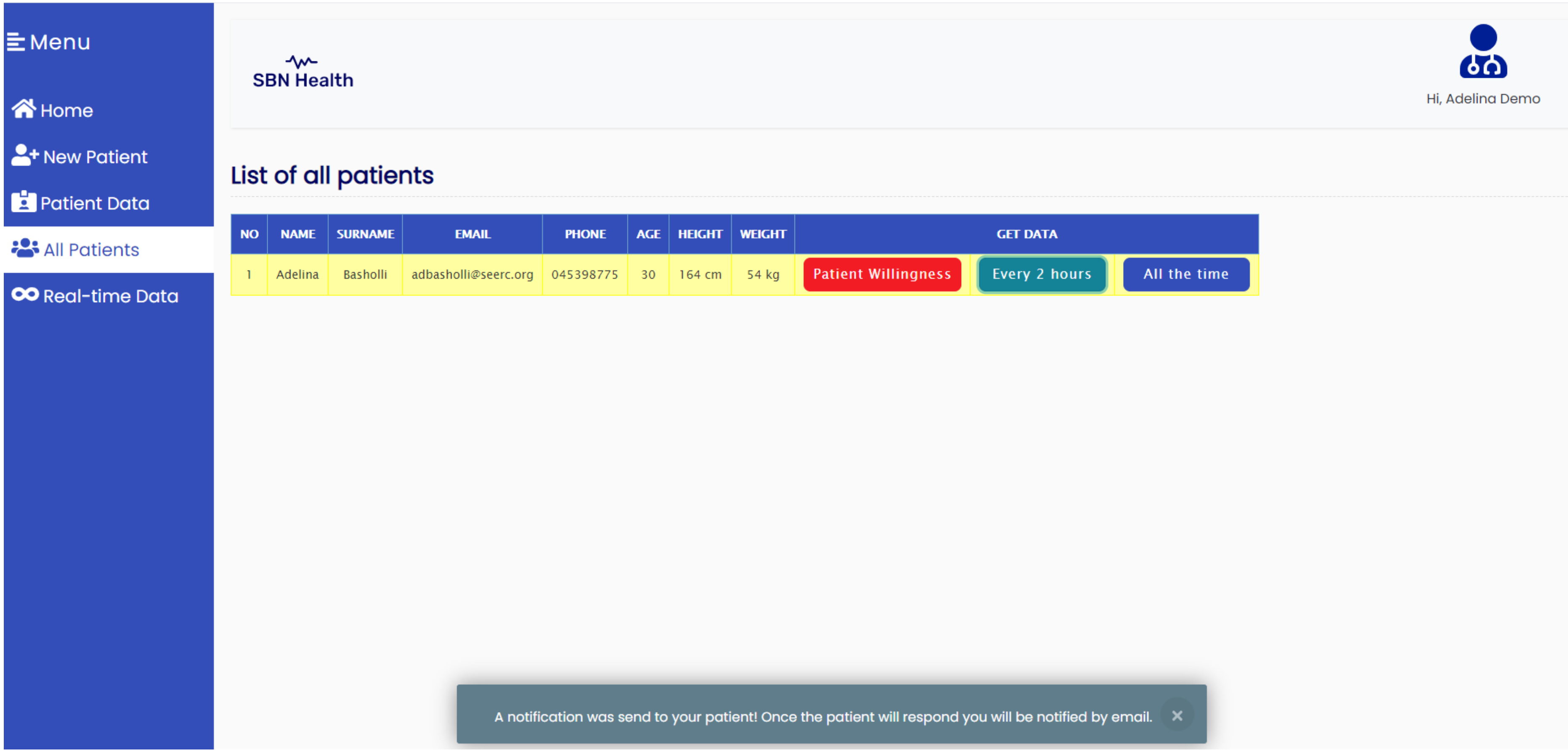


New Patient
Patient Data
All Patients
Real-time Data
Patient Data
Arlind Sopi
adbasholli+01@gmail.com
044112233
25 years old
182 cm
63 kg
Street Bajram Kelmendi, Prishtina, 10000, Kosovo
Table
Graph
Heart Rate
Oxygen Saturation
Systolic Blood Pressure
Diastolic Blood Pressure
22-01-2021 22:27:00
Creation Date

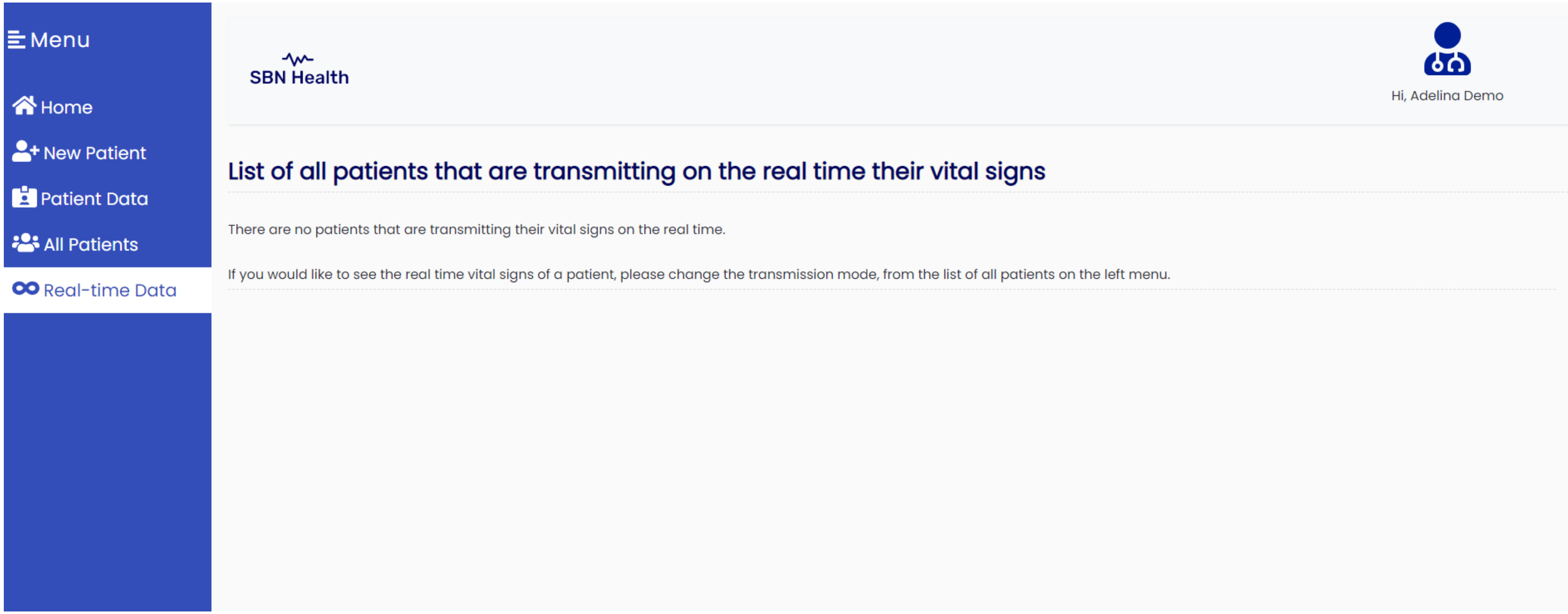
Appendix D.9 Web app GUI, List of all patients and their transmission mode



Appendix D.10 Web app GUI, Changing a patient data transmission mode



Appendix D.11 Web app GUI, Real-time data monitoring



Appendix D.12 Web app GUI, Edit profile of a healthcare professional