Integration of Mobile Technologies with Routine Healthcare Services in Mozambique
To
My beloved daughters Xaron & Xiluva
Örebro Studies in Informatics 13

José António Nhavoto

Integration of Mobile Technologies with Routine Healthcare Services in Mozambique
Abstract


Mobile technologies are emerging as one way to help address health challenges in many countries, including in Least Developed Countries. Mobile technology can reach a large share of the population but in order to provide effective support to healthcare services, technology, information collection and dissemination, and work processes need to be well aligned. The thesis uses a design science methodological approach and mixes qualitative and quantitative data analysis to address the question of, How can mobile technologies be effectively integrated with routine healthcare services?

The study concerns the design, implementation, and evaluation of a mobile technology-based system, called SMSaúde, with the aim of improving the care of patients with HIV/AIDS and tuberculosis in Mozambique. The work started with the elicitation of functional and user requirements, based on focus group discussions. An important challenge, as in many mHealth interventions, was the integration with routine healthcare services and the existing IT systems, as well as developing a scalable technical structure. The system has now been in routine use since 2013 in more than 16 healthcare clinics in Mozambique. Evaluation was done by a randomised controlled study. Analysis of patient records showed that retention in care in urban areas was significantly higher in the intervention group than in the control group. In a user study both patients and health professionals were very positive to the system. The thesis contributes to research by demonstrating how information system artefacts can be constructed and successfully implemented in resource-constrained settings. The practical contributions include the designed artefact itself as well as improved healthcare practices and mHealth policy recommendations.

Keywords: mobile technologies, mobile health, mHealth, Least Developed Countries, Mozambique, mobile phones, information systems artefact, design science research.

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**List of papers**


### Abbreviations

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<th>Full Form</th>
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<tr>
<td>AIDS</td>
<td>Acquired Immunodeficiency Syndrome</td>
</tr>
<tr>
<td>App</td>
<td>Application</td>
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<tr>
<td>ARK</td>
<td>Absolute Return for Kids</td>
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<td>ART</td>
<td>Antiretroviral Therapy</td>
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<td>CNCS</td>
<td>Conselho Nacional de Combate ao HIV e SIDA</td>
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<td></td>
<td>Mozambique National HIV/AIDS Council</td>
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<tr>
<td>DB</td>
<td>Database</td>
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<tr>
<td>DFID</td>
<td>Department for International Development</td>
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<td>DSR</td>
<td>Design Science Research</td>
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<td>EU</td>
<td>European Union</td>
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<td>EPTS</td>
<td>Electronic Patient Tracking System</td>
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<td>GSM</td>
<td>Global System for Mobile Communication</td>
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<td>GSMA</td>
<td>GSM Association</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<td>HIS</td>
<td>Health Information System</td>
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<td>HIV</td>
<td>Human Immunodeficiency Virus</td>
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<td>ICT</td>
<td>Information Communication and Technology</td>
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<td>IT</td>
<td>Information Technology</td>
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<td>IS</td>
<td>Information Systems</td>
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<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
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<td>LDCs</td>
<td>Least developed countries</td>
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<td>LMICs</td>
<td>Low and middle income countries</td>
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<tr>
<td>MoH</td>
<td>Ministry of Health</td>
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<tr>
<td>NGO</td>
<td>Non-governmental organization</td>
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<tr>
<td>PDAs</td>
<td>Personal Digital Assistants</td>
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<tr>
<td>PC</td>
<td>Personal Computer</td>
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<tr>
<td>SMS</td>
<td>Short Message Service</td>
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<td>TB</td>
<td>Tuberculosis</td>
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<tr>
<td>UNAIDS</td>
<td>United Nations Programme on HIV/AID</td>
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<td>UNICEF</td>
<td>United Nations Children’s Fund</td>
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<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
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<td>WHO</td>
<td>World Health Organization</td>
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Terms and definitions

**Health information system:** an integrated effort to collect, process, report and use health information and knowledge to influence policy-making, programme action and research (Lippeveld, 2001).

**Electronic health (eHealth or e-Health):** the use of ICT for health. In its broadest sense, eHealth is about improving the flow of information, through electronic means, to support the delivery of health services and the management of health systems (WHO, 2012).

**Least developed countries (LDCs):** a group of countries, according to the United Nations, that have the lowest gross national income, weak human assets and highest degree of economic vulnerability.

**Low- and middle-income countries (LMICs):** a group of countries with a gross national income per capita between $1,026 and $4,035, for the current 2017 fiscal year (World Bank, 2017b).

**Mobile health (mHealth or m-Health):** an area of electronic health that provides health services and information via mobile technologies such as mobile phones and PDAs (WHO, 2011).

**Information and Communications Technology (ICT):** a diverse set of technological tools and resources used to communicate and create, disseminate, store, and manage information (Blurton, 1999). ICT include telecommunication technologies (telephony, cable, satellite, TV and radio, computer-mediated conferencing, video conferencing) as well as digital technologies (computers), information networks (internet, World Wide Web, intranets and extranets) and software applications (Chisenga, 2006). In this thesis, ICT focuses on the internet, mobile networks, computers and mobile technologies as well as software and the services that they enable.
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1. Introduction

This thesis analyses how mobile technology, a class of Information and Communications Technology (ICT), can be effectively integrated with routine health care services in Mozambique, a Least Developed Country. Least Developed Countries (LDCs) as defined by the United Nations are countries with the lowest gross national income, weak human assets and the highest degree of economic vulnerability.

Healthcare systems in LDCs struggle with limited resources and capabilities, such as the scarcity of money, poor infrastructure, a lack of access to and affordability of preventive care, a shortage of skilled healthcare personnel, and an unequal distribution of health professionals and services within the country (Mills, 2014). The inadequate healthcare systems in LDCs intensify a variety of health problems that include malaria, tuberculosis (TB), and Human Immunodeficiency Virus Infection and Acquired Immune Deficiency Syndrome (HIV/AIDS) (Stevens, 2004; UNAIDS, 2016; WHO, 2015b, 2016a).

Healthcare systems require functional health information systems (HIS) in order to improve the health of the population (Yazdi-Feyzabadi, Emami, & Mehrolhassani, 2015). According to Lippeveld (2001), HIS is an “integrated effort to collect, process, report and use health information and knowledge to influence policy-making, programme action and research”. HIS can enable decision-makers at all levels of the health system to identify progress, problems, and needs; make evidence-based decisions on health policies and programs; and optimally allocate scarce resources (Simba & Mwangu, 2004; WHO, 2008).

Many LDCs have invested heavily in improving HIS, but the challenge continues to lie in how to achieve successful and useful HIS – despite a considerable number of promising projects and the potential benefits of the new technologies. A challenge to a functional HIS is the lack of information integration. In HIS, the information comes from different sources, including paper-based systems and computer-based systems. The lack of integration of these systems leads to an inadequate data flow between them, resulting, for instance, in a lack of access to patient information that could be used to devise strategies to better address patients’ health problems and health decision-making (Meyer et al., 2005).

This thesis explores the potential of ICT in the healthcare sector (commonly referred as electronic health [eHealth]) to strengthen HIS and to address the challenges of the integration of information systems with health...
services. More precisely, the thesis addresses the issue of the integration of mobile technologies with routine health services in the case of Mozambique. In the context of this thesis, ICT include the internet, computers, telephones (fixed and mobile), and other wireless devices (Vandelanotte et al., 2016).

The thesis explores the opportunities of mobile health (mHealth), a subset of eHealth. Generally, eHealth refers to tools and services using ICTs that can improve the prevention, diagnosis, treatment, monitoring and management of a diverse range of diseases (ENS4Care, 2015; European Commission, 2012). mHealth concerns the use of mobile technologies (e.g. mobile phones, Personal Digital Devices (PDAs)) as integrated within the healthcare delivery system (Istepanian & Lacal, 2003). The mHealth research domain seeks to identify appropriate mobile-based applications and implementation strategies to address public health challenges.

Governments are expressing interest in mHealth as a complementary strategy for strengthening HIS and achieving the health-related Millennium Development Goals, especially in LDCs (WHO, 2011). This interest has led to a series of mHealth deployments worldwide that are providing early evidence of the potential for mobile and wireless technologies.

mHealth applications are being tested in such diverse scenarios as improving timely access to emergency and general health services and information; managing patient care; reducing drug shortages at health clinics; enhancing clinical diagnosis and treatment adherence; and in programmes reducing the burden of the diseases linked with poverty, including HIV/AIDS, malaria, and TB, among others (WHO, 2011). Vandelanotte et al. (2016), who reviewed literature on the impact of mHealth interventions in low- and middle-income countries (LMICs), found that there is a growing evidence base for the efficacy of mHealth interventions, particularly in improving treatment adherence, appointment compliance, data gathering, and developing support networks for health workers; however, the quantity and quality of the evidence is still limited in many respects. mHealth research projects are not only under-theorised but include ambiguous descriptions of interventions and their mechanisms, hindering the interpretation, replication, scaling and effective translation of the research to practice (Catalani, Philbrick, Fraser, Mechael, & Israelski, 2013; Chib, van Velthoven, & Car, 2015; Higgs et al., 2014; Lee et al., 2016). Catalani et al. (2013) and Chib et al. (2015) further found that few studies used theory or methodological designs to explain the use of mobile phones for healthcare needs or the connections between particular development processes and health outcomes. Furthermore, the literature reveals that there are many systems that have
not been scaled up. For instance, Lemaire (2011) found that in Uganda, 23 of 36 mHealth initiatives did not move beyond the pilot phase. One possible explanation for this is that the problem situation is not well understood, hence the solutions are not functional.

This thesis investigates the mechanisms for the design, development and implementation of solutions that can be scaled up. A design science research (DSR) methodological approach is used to guide and motivate the process of the design and development of an artefact called SMSaúde. The DSR approach was chosen because the approach involves a rigorous process to design artefacts that solves the observed problems (Hevner, March, Park, & Ram, 2004). The artefact was designed and developed in cooperation with medical personnel who had a good understanding of the problem. This allowed for the design and development of the artefact. It was tested and evaluated iteratively, which is a main point of DSR (as opposed to some other methods, where design comes first and implementation after, DSR iterates). The information systems artefact was integrated with the routine healthcare services of HIV/AIDS and TB treatments, thus making the health information infrastructure more robust for use in urban and rural areas in Mozambique. The information systems artefact was implemented initially in four healthcare centres and scaled up, in a second DSR process, to 16 healthcare centres. This thesis also investigates the impact of the implemented mHealth artefact. The impact of the mHealth artefact is investigated in two ways: 1) patients’ outcomes and 2) the perspectives of healthcare workers and patients. Furthermore, this thesis looks at the current state of mHealth implementation in Mozambique. The thesis also investigates the success/failure factors and challenges for the development and deployment of mHealth applications.

1.1 Scope of the thesis
This thesis project was conducted within the discipline of information systems with a focus on people, processes and technology. Theory, method and general knowledge from the information systems field are applied in healthcare to address the issue of the integration of information technology with routine healthcare services.

The recognition of the existence of only a low capacity to provide strategic and cohesive leadership to the health sector in the context of the use of ICTs has, in recent years, contributed to the efforts of national organisations trying to promote broader health system development initiatives. These in-
clude findings ways to integrate emerging technologies, and more specifically, mobile technologies, into routine health care delivery. However, achieving this integration in practice is a complex process characterised by tensions between the “system designers” (management and planning specialists), who promote the overall operation of the health sector, and the specific programme managers, who are concerned with particular disease control strategies. The following quote illustrates some of these tensions:

“Management and planning specialists have often adopted a narrow formulation of health care reforms which, in some cases, pretend to an almost universal legitimacy, proclaimed as beneficial, irrespective of the context in which they are designed. Ideological, economic and political pressures, often emanating from outside the health sector, have shaped health reforms while concern for epidemiological, [informational] and demographic issues and technical approaches to health care interventions have tended to be secondary considerations. Health reforms have been developed which pay little attention to the particular features of specific disease control policies. At the same time, [specific] programme managers have not engaged actively with reforms in such a way as to influence the appropriate design for reformed health sector…” (Collins et al. 2002, p.141).

Chilundo (2004) argues that “one key aspect, though often ignored, of ‘unifying’ specific health systems includes the consequent need to also integrate the respective information system”. In this thesis, the integration of information systems is seen as a process of bringing together health data from different HIS into one system that can be used for decision-making.

This research is concerned with the crucial issue of integrating the routine information systems of HIV/AIDS and TB with mobile technologies. These two diseases represent some of the most major health problems in many LDCs. Substantial progress has been made in reducing the incidence of these diseases, however TB and HIV co-infections are a growing issue in many resource-limited settings (Pawlowski, Jansson, Sköld, Rottenberg, & Källenius, 2012), which creates complex challenges for the management of these health programmes. These complex challenges force health managers to re-strategise their approaches, including those relating to information systems.

The issue of integration is not only important to health care, but also to broader information systems research and practice. Many organisations, private and public, usually face multiple challenges as they seek to progress through standalone information systems to a context where various information systems are integrated to serve specific purposes. These challenges,
as argued by Chilundo (2004), include changing various things, such as organisational environments, existing policies, data forms and applications, data channels, technology and human skills. Therefore, information systems integration is not merely a simple technical process of “solving problems”, but it goes beyond that to also involve political, cultural, social and economic alliances (Webster, 1995).

1.2 Problem statement and motivation
ICT and in particular mobile technologies can be utilised in healthcare to improve HIS, service provision and health outcomes. However, despite the numerous research studies and trials that show the emerging need for these kinds of services and the recognised potential of this by national health authorities in a number of different countries, mobile devices and applications are still not widely used in the healthcare sector as a standard way of delivering healthcare services to patients and healthcare providers and managing health-related information.

On the other hand, numerous stand-alone applications offering people health management services on mobile devices can be found on the market. For example, there are a great number of health-related applications available in the App Store (a digital distribution platform for mobile apps [applications] on iOS) and in the Google Play store (a digital distribution platform for the Android operating system). However, these applications are not connected to professional health-related services and their information management. Therefore, this thesis tries to contribute by building an information systems artefact that is connected with real-life healthcare settings, and which has an influence on the healthcare processes.

Despite the existence of health-related mobile applications that show recognised potential, the fact that they are not integrated with other services in HIS emphasises the requirement for further research work. For instance, Mars (2013) found that only a few initiatives in sub-Saharan Africa have been successfully integrated into routine clinical practice, and the published information on their use is sparse. In addition, the shortage of research on mHealth in Africa, where the majority of LDCs are – and on Mozambique particularly – was a practical motivation for this thesis. Conducting the research in Mozambique, particularly investigating how mobile phones could be integrated with routine health care services, could potentially help address this deficit in mHealth literature, which to me as a Mozambican presents a strong personal incentive. Mozambique also presented a good case study, as I know it fairly well. In practice, the lack of a mobile phone-based
system that could enable efficient communication between healthcare providers and patients in rural and urban healthcare centres in Maputo, Mozambique was a problem that needed a solution. Mechael et al. (2010) suggested that the current mHealth single-solution focus needs to be replaced by mHealth as an extension and integrator of underlying HIS along the continuum of care. This motivated the design of a solution – a mobile phone-based system that sent automatic Short Message Service (SMS) text messages – based on the local needs of healthcare workers and patients. The solution was integrated into healthcare practice. Understanding the needs and interests of healthcare workers is important for the uptake of an mHealth solution, especially if it helps to achieve programme objectives (Chaiyachati et al., 2013).

Addressing the issue of the lack of mHealth integrated communication systems required not only the design of a technical system, but also the use of theoretical and methodological approaches that could drive the entire process. Both theoretical and methodological rigour are necessary in order to influence practice and policy (Chib, 2013). Such a process, as argued by Chib (2013), needs to follow a pathway of input-mechanism-outputs, with the input factors focusing on technology introduction, the mechanism factors investigating psychosocial and individual motivations for adoption, and the outputs including healthcare system processes and healthcare providers’ expectations as well patient health indicators. This suggests a theoretical and methodological perspective when addressing the design, development and implementation of mHealth solutions. The review by Chib et al. (2015) of 53 mHealth studies in low income and low and upper middle-income countries from 2000-2013 showed that a majority of studies ($n=32$) focused on technological inputs with little theoretical support, suggesting a prevailing techno-optimistic view. While only a few studies ($n=15$) discussed health outputs, even fewer ($n=6$) investigated the mechanisms of adoption and appropriation. A fundamental finding was the scarcity of studies that could satisfactorily explain the entire pathway from technology adoption to health improvements via the implementation of mHealth. This motivated the design of the solution using a well-established information technology research methodology – called design science research – which offers specific guidelines or principles for the construction, evaluation and iteration of artefacts within research projects (Hevner & Chatterjee, 2010a).

Many HIS in LDCs are in need of interventions that not only integrate different information systems but also look at how users perceive the bene-
fits of these interventions, and also consider what the effects on health outcomes and work practices are. In this regard, in their review of mHealth interventions in LMICs, Mechael et al. (2010) found that “studies in peer-reviewed journals are generally weak and the results focus on intermediary benefits such as cost savings and improved reliability of data but do not go to the next level to show improved workflow, efficiency, quality of care, and/or health outcomes”. Therefore, it was my goal to contribute to this type of evidence.

Despite the fact that Mozambique has one of the least developed telecoms systems in Africa, the mobile market is the most successful segment, with a mean annual growth rate (CAGR) of investment between 2003-2013 of 40%, going from 435,757 to 12.5 million subscribers in that period (Bettencourt, 2015; Varatojo, 2014). By the end of 2017, it is estimated that this number will rise to 18.5 million subscribers, implying 6 million net additions and a CAGR 2013-2017 of 10.5% (Varatojo, 2014). By 2013, there were one million 3G & 4G internet subscribers; by 2018, experts expect 3G subscriptions to reach 15.5% of the total subscriber base (Bettencourt, 2015). These conditions present opportunities for more mHealth interventions. Like in other LDCs, in Mozambique there is a proliferation of mHealth pilots, with few moving forward to being scaled up and little evidence to inform researchers on whether, when, and how pilots might expand countrywide (Tomlinson, Rotheram-Borus, Swartz, Tsai, & Niedzinski, 2013). With this in mind, it is important to investigate why some projects fail/succeed and what are the challenges involved. Although challenges in the context of eHealth – the same issues could apply to mHealth – have been investigated, for example, by Mechael et al. (2010), Barbour et al. (2013), Wambugu et al. (2016), more evidence is needed in a country-specific context. It is my hope that, in identifying the key mHealth success/failure factors and challenges, more proactive actions can be undertaken to create an enabling environment in Mozambique to promote the scaling up of projects, sustainability, and evidence-based research.

1.3 Research aim and questions

The aim of this thesis is to understand and promote the use of integrated mobile technologies in healthcare in LDCs.

The research question of this thesis is:
How can mobile technologies be effectively integrated with routine healthcare services?

The research question is divided into five sub-questions. Each question is represented by one paper. These sub-questions are:

1) What is the potential of using mobile technologies to improve healthcare?
2) How can we design, develop and implement an integrated mobile phone text messaging system that could be used for HIV/AIDS and TB?
3) What are the effects of the use of a mobile phone-based system on retention in treatment?
4) What are the perspectives of healthcare workers and patients on an integrated mobile phone-based system?
5) What are the applications, challenges, success/failure factors and implications for the policy of mHealth interventions in Mozambique?

The first question aims to provide a review of the literature related to the use of mobile technologies in health-related research for improving healthcare. This will help to identify the areas of use of mobile technologies and to understand the needs for a solution in the context of Mozambique.

The second question discusses the requirements for the integration of a mobile phone-based system into HIV and TB treatment. The question aims to identify and define the requirements for the design, development, and implementation of a text messaging system integrated into the electronic medical records of HIV/AIDS and TB patients.

The third question aims to evaluate whether regular mobile phone text reminders improved the retention of patients in HIV/AIDS care in Mozambique.

The fourth question aims to study the perspectives of patients and healthcare workers on an mHealth intervention aiming to support HIV/AIDS and TB treatment. In particular, it examines the perceptions of users of the integrated SMS system and discusses how demographic factors affect users’ attitudes toward the system.

The fifth question aims to identify and examine the various applications of mobile technologies in healthcare in Mozambique. In addition, it also seeks to determine and discuss the challenges faced in the implementation
of mHealth services. The question helps to draw up the implications for the policy design of mHealth in Mozambique.

1.4 Papers included in this thesis

This thesis is based on the findings of five papers, the data for which was collected during the study period for this thesis. The complete reference to the papers is presented in the List of papers, and their contributions to the research questions are mapped in Table 1.1. The complete papers are available at the end of this thesis.

These papers together address the research question: “How can mobile technologies be effectively integrated with routine healthcare services?”

The contribution of each paper is mapped with sub-questions, as presented in Table 1.1 below.

<table>
<thead>
<tr>
<th>Research question</th>
<th>Research paper</th>
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<tr>
<td>RQ1. What is the potential of using mobile technologies to improve health care?</td>
<td>Paper 1: Mobile Technologies and Geographic Information Systems to Improve Health care Systems: A Literature Review</td>
</tr>
<tr>
<td>RQ2. How can we design, develop and implement an integrated mobile phone text messaging system that could be used for HIV/AIDS and TB?</td>
<td>Paper 2: SMSaúde: Design, Development, and Implementation of a Remote/Mobile Patient Management System to Improve Retention in Care for HIV/AIDS and Tuberculosis Patients</td>
</tr>
<tr>
<td>RQ3. What are the effects of the use of a mobile phone-based system on retention in treatment?</td>
<td>Paper 3: SMSaúde: Evaluating Mobile Phone Text Reminders to Improve Retention in HIV Care for Patients on Antiretroviral Therapy in Mozambique</td>
</tr>
<tr>
<td>RQ4. What are the perspectives of healthcare workers and patients on an integrated mobile phone-based system?</td>
<td>Paper 4: Mobile Health Treatment Support Intervention for HIV and Tuberculosis in Mozambique: Perspectives of Patients and Healthcare Workers</td>
</tr>
<tr>
<td>RQ5. What are the applications, challenges, success/failure and implications for the policy of mHealth interventions in Mozambique?</td>
<td>Paper 5: Use of Mobile Technologies to Improve Health Care in Mozambique: Success/Failure Factors, Challenges, and Policy Implications</td>
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Table 1.1. The link between the research question and the research papers
1.5 Structure of the Thesis

The thesis is organised as follows. Following this introductory chapter, Chapter 2 positions my research within the information systems research field, with a special focus on developing countries. It also presents a brief literature review on eHealth and mHealth, including definitions, opportunities, and applications, with a focus on the context of developing countries.

Chapter 3 presents the research context. Chapter 4 presents and discusses the main methodological approach adopted for the research. Here, design science research is described as the baseline for this study, drawing upon the qualitative and quantitative methods described in Chapter 5. Chapter 5 also presents the data collection techniques and data analysis procedures, and discusses the ethical considerations of the study. Chapter 6 presents the technological system: the SMSaúde system. Chapter 7 presents a summary overview of the papers. Finally, in Chapter 8, I present a summary of the research with my contributions and final conclusions.
2. Information systems for health

In this chapter, I present the literature using the terms HIS, eHealth and mHealth, both as regards all countries and with a special focus on the context of developing countries. The terminology may seem confusing, as the partly overlapping meanings come from different focuses and also reflect a shift over time of the most frequently-used terms.

2.1 The concepts HIS, eHealth and mHealth

The term HIS has in some literature been taken to mean health information systems, and is then a very broad term that includes all of the uses of ICT for health purposes. When the authors have an information systems view of the world, the studies include not just the technology but also the people and the processes in which the artefacts are used. However, there is also a rich literature where HIS means hospital information systems. Much of it is quite old, stemming back to the 1980s, but reflects the fact that more or less comprehensive IT artefacts were developed in some countries first for the hospital sector (often starting in university hospitals), marketed by different commercial companies. A number of both purely medical as well as administrative functions could be included in the concept of hospital information systems. In the studies described in the next section on HIS in developing countries, the term is used in the wide sense to mean any use of information systems for health. Today, the more dominant terminology is ‘eHealth’, but the above is usually identical to what is covered under this term in more modern work.

In this thesis, I use the eHealth term in the broad sense to mean any use of ICT for health purposes, in line with the original documents of the WHO when the term was introduced as an action item by the World Health Assembly in 2005. Finally, mHealth is the most recently established term, which I consider as a subset of all eHealth in which mobile devices, often a mobile phone, are used for some health purpose.

2.2 HIS in developing countries

In recent years, HIS in developing countries have received significant attention from both health care practitioners and the information systems research community (Nyella, 2011). In addition, various organisations, including governments, international agencies, and non-government organisations (NGOs), have put a lot of effort towards achieving the goal of better
healthcare services provision in these locations, through various interventions and approaches.

A proper HIS would help to improve the healthcare sector hugely, by providing a useful tool to assist in planning, monitoring, and evaluation (Mutale et al., 2013). However, the status of HIS remains an issue of high concern. The HIS in place are often under-performing, where various problems, including data quality (which includes accuracy and validity, reliability, completeness, legibility, currency and timeliness, accessibility, meaning or usefulness, confidentiality, and security) (Chilundo, Sundby, & Aanestad, 2004; WHO, 2003), and the lack of an information culture (Mukred, Singh, & Safie, 2013), both persist.

Unfortunately, HIS in most countries are inadequate in providing the needed management support. Current HIS in developing countries are widely seen as management obstacles rather than as information systems to be used for data collection, manipulation, dissemination, decision- and policy-making, because of the irrelevance of the information gathered, the lack of timely reporting and feedback, the poor quality of data, duplication and waste among parallel HIS; plus the poor use of information, the lack of skills for data interpretation and utilisation, the lack of policy guidelines on information, and the lack of flexible systems (Chilundo et al., 2004; Kimaro & Twaakyondo, 2005; Wagenaar et al., 2015).

Various factors are the root causes of underperforming HIS in developing countries, including the under-developed HIS infrastructure, inadequate skill levels, the high workloads of the data collection staff, and most importantly, the organisation of the HIS themselves (Sheiki, 2015). In addition, the healthcare sector experiences fragmented information systems. Thus, the collection of repeated data, that fails to address sector-wide needs, and the inconsistent use by staff, who are already overburdened due to the high workload caused by the large number of clients and patients they serve (Mosse & Sahay, 2003), compromises meeting the need for evidence-based care and care management in this sector.

Different programmes focusing on the control of particular diseases such as HIV/AIDS, TB, and malaria, or on special services such as immunisation, child health, nutrition and reproductive health, or programmes that deal with support in medical supplies or capacity development, have developed localised information systems to help in the planning, monitoring and evaluation of the offered service (Simba & Mwangu, 2004; Walsham & Sahay, 2006). Usually, these programmes receive funding from bilateral and mul-
tilateral donors. In most cases, one programme receives support from multiple sources, making the situation complicated in terms of the information demand and accountability (Chilundo & Aanestad, 2004; Lippeveld, 2001).

In recognition of the potential damage caused by information system fragmentation, countries and donors are now seeking a greater degree of HIS integration, facilitated through the use of ICT-based data techniques. These data shall come from different sources at different levels, from the lowest level to the sub-national and national levels, and shall be based on the core indicator sets necessary for healthcare management (WHO, 2008). Rather than a centralising design and management process, this design should seek a “balance between the top-down initiatives dictating data demand and the bottom-up actual data demand and use of information systems tools in order to involve all necessary stakeholders in the design process” (Sheiki, 2015).

HIS integration in developing countries is considered as an important approach for the rationalisation and unification of disparate systems (Nyella, 2009). However, guaranteeing HIS integration in these contexts has proven to be challenging, generally due to both the social and technical factors surrounding the process of integration. Some particularities that challenge HIS integration are related to politics, institutional conditions, high resource constraints (e.g. infrastructure, human resources, financial resources), high disease burdens and the particularities of the diseases (Chilundo, 2004; Sahay, Monteiro, & Aanestad, 2009).

As part of the efforts for strengthening HIS in developing countries, electronic health (eHealth) can play an important role.

### 2.3 eHealth

The term eHealth has been in use since 1999, apparently first used by industry leaders and marketing people rather than academics (Eysenbach, 2001). The term was highly influenced by surging interests in business areas such as e-commerce, e-business and e-solutions, in an attempt to convey the promises, principles and excitement of e-commerce to the health area (Eysenbach, 2001; Mitchell, 1999). Mitchell (1999) points out that eHealth is a subset of e-commerce, and notes that eHealth is not simply about business transactions. He then defines eHealth “as the use in the health sector of digital data – transmitted, stored and retrieved electronically – for clinical, educational and administrative purposes, both at the local site and at a distance” (Mitchell, 1999).
Nowadays, the eHealth term is commonly used in relation to ICT deployments in healthcare (Catwell, Sheikh, Majeed, Sheikh, & Sheikh, 2009). Although there have been several attempts to define eHealth, there is still no universally accepted definition of this term (Catwell et al., 2009; Eysenbach, 2001; Oh et al., 2005; Pagliari et al., 2005). Examples of definitions include:

- “e-Health is a consumer-centred model of health care where stakeholders collaborate, utilising ICTs including Internet technologies to manage health, arrange, deliver and account for care and manage health care systems” (Alvarez, 2002).
- “eHealth is the application of information and communications technologies (ICT) across the whole range of functions that affect healthcare, from diagnosis to follow-up” (Silber, 2003).
- According to the WHO (2006), eHealth is defined simply as “the use of ICT for health”. This should be understood in its broadest sense; eHealth is about “improving the flow of information, through electronic means, to support the delivery of health services and the management of health systems” (WHO, 2012).

Most definitions view technology as a tool, but eHealth is more than a mere technological development (Eysenbach, 2001). Most often, eHealth is used to refer to the application of ICT to the healthcare sector, where it is perceived that quick wins can be achieved, instead of taking the systemic view that may bring wider reforms to the health system (ITU, 2008). Catwell et al. (2009) argue that “eHealth should encompass the full spectrum of ICTs, whilst appreciating the context of use and the value they can bring to society”. A definition that includes these various facets is proposed by Eysenbach (2001, p.1):

“e-Health is an emerging field of medical informatics, referring to the organisation and delivery of health services and information using the Internet and related technologies. In a broader sense, the term characterises not only a technical development, but also a new way of working, an attitude, and a commitment for networked, global thinking, to improve healthcare locally, regionally and worldwide by using information and communication technology.”
2.4 eHealth systems and their benefits

The use of eHealth services offers many possibilities for improving the health of populations and health systems (Bates & Wright, 2009; Blaya, Fraser, & Holt, 2010; Chetley et al., 2006; WHO, 2006). This section classifies eHealth systems on the basis of their use and their functionality. In addition, it describes the potential benefits of eHealth systems for healthcare. The potential benefits and uses are discussed from the viewpoint of citizens and healthcare professionals. The descriptions are both in the context of developed and developing countries.

2.4.1 eHealth systems

The aim of this subsection is to provide examples of eHealth systems, including a description of their use, and not to provide an exhaustive list.

eHealth systems and services are location-independent, i.e., they can be used locally (e.g. hospitals, doctors’ workplaces) or remotely, as is inherent in the term “tele” (teledermatology, telesurgery, telediagnosis and so on) (ITU, 2008). eHealth systems include those that are described below.

**Electronic health record (EHR)** is considered as a “comprehensive, cross-institutional, and longitudinal collection of a patient’s health and healthcare data” (Hoerbst & Ammenwerth, 2010). This term has been widely used in recent years as a replacement for such terms as: electronic medical records, computerised medical records, and even hospital information systems. EHR is the preferred term, used by policy makers, vendors and in the international standardisation of health informatics, e.g., in ISO. A comprehensive and connected record of the health status and healthcare activities and plans of patients is central to modern health systems, but also demanding, and it is often only partly implemented in all its possible functionality, and far from ubiquitous. For example, it is very rare in Least Developed Countries. EHR is mainly created to serve health professionals in a health care organisation in their clinical care of an individual patient. However, EHR also has many secondary uses where the data is reused for other purposes, such as public health data collection for planning purposes, medical and health systems research or quality management, and for interaction with patients/citizens.

The use of eHealth systems seeks to improve healthcare services locally, regionally and worldwide (Eysenbach, 2001). Their use in the healthcare sector includes clinical, preventive, educational, research and administrative purposes, both at the point of care and remotely (Minichiello, Rahman, Dune, Scott, & Dowsett, 2013).
Telemedicine. The term can be defined as the practice of medicine at a distance. According to Bashshur (1997), cited by Chou & Chou (2002, p. 323), telemedicine can be described as follows: “Broadly, telemedicine involves the use of modern information technology, especially two-way interactive audio/video telecommunications, computers, and telemetry, to deliver health services to remote patients and to facilitate information exchange between primary care physicians and specialists at some distances from each other...(and) a telemedicine system is an integrated, typically regional, healthcare network offering comprehensive health services to a defined population through the use of telecommunications and computer technology”. Telemedicine includes telemonitoring and teleconsultation, as described below.

Telemonitoring is the “transmission of physiologic data, such as an ECG [electrocardiogram], blood pressure, weight, respiratory rate, and other information, such as self-care, education, lifestyle modification and medicine administration; using other technology like broadband, satellite, wireless or Bluetooth” (Inglis, 2010). A simple definition by Meystre (2005) states that telemonitoring is “the use of information technology to monitor patients at a distance”.

Teleconsultation: This type of telemedicine is used for several different purposes. The concept can mean a “type of telemedicine application used by the physicians to inspect the medical data of the patients located in remote areas” (Altaei & Abdul-Mehdi, 2013). However, teleconsultation directly between patients and health professionals is also beginning to be used in urban areas. Perhaps the most widely used type of teleconsultation is between two different types of health professionals. Usually, one party is more specialised and is not in direct contact with the patient, and one party is less specialised (a primary care physician or a nurse) and more remotely placed, with the direct care responsibility for the patient, who is often present during the teleconsultation session. A recent review of physician-physician teleconsultations found that: “Most teleconsultations were inland experiences (no=135), and the USA, Italy and Australia were the three top countries in this group. Non-specialists health care providers/cent[r]es were the dominant group who requested teleconsultation (no=130). Real time, store and forward, and hybrid technologies were used in 50, 31, and 16.7 percent of articles, respectively.” (Deldar, Bahaadinbeigy, & Tara, 2016).

Virtual healthcare teams: These are teams “consisting of healthcare professionals who collaborate and share information on patients through digital equipment (for transmural care)” (Fertman 2015, p.312).
ePrescription: This describes “access to prescribing options, printing prescriptions to patients and sometimes electronic transmission of prescriptions from doctors to pharmacists” (Fertman 2015, p.312).

2.4.2 eHealth benefits
Even though there are differences in terms of how health conditions are dispersed and in terms of their management between developed countries and developing countries, the potential of eHealth is similar in both contexts. An eHealth system designed and implemented in a developed country can work in a developing country. Despite criticism over the ad-hoc efforts of eHealth systems developed in the context of rich countries, developing countries can benefit from the same IT artefacts as developed countries. This can be achieved with care, especially if such information systems artefacts are adapted to the context of the country.

The great potential of eHealth systems lies not only in the advance of technology, but also in the people who implement them. Many countries have seen the emergence of new approaches to health problems, driven mainly by the situation of health, technology advances, the needs of citizens/patients, and the commitment of governments. Governments use eHealth as a solution to address health problems at different levels, including to improve healthcare globally, regionally and locally. For instance, the WHO has developed guidelines and strategic approaches that strengthen the need for different actors in the healthcare system to network for the best results of the health of the nation. This requires that actors adapt to particular needs but also contribute to the larger healthcare system.

eHealth has the potential to empower citizens/patients through online health system (such as healthcare portals and patient portals) – they are widely used to disseminate health information to promote the health behaviour of citizens/patients – in ways that mean they can be better informed about disease prevention. Citizens/patients can also have confidence in service delivery and they can exercise reasonable levels of choice in a way that can help them to take an active role in managing their health. In addition, citizens/patients can take responsibility for their own health and make decisions about their healthcare. In turn, this can motivate the self-management of their health. A study in Denmark, Germany, Greece, Latvia, Norway, Poland and Portugal by Santana et al. (2011), found that “citizens using the Internet to decide whether to consult a health professional or to get a second opinion are likely to be frequent visitors of health sites, active participants of online health forums and recurrent buyers of medicines and
other health related products online”. With the increasing number of internet users, healthcare professions will possibly be increasingly challenged by knowledgeable and empowered patients. Despite the positive effects of online health systems, problems might arise due to some citizens having little or no medical knowledge, especially about terminologies and specific descriptions. Consequently, problems might arise such as a difficulty in understanding and using the information, and even harm from wrongful self-diagnosis and treatment (Benigeri & Pluye, 2003).

EHRs are used in various contexts to help improve the care of various types of health conditions. A review of the benefits of EHRs found that much of the literature focuses on “clinical decision support systems, computerized order entry systems, and health information exchange” (Menachemi & Collum, 2011). The potential benefits of these applications, as reported by Menachemi & Collum (2011), include “clinical outcomes (e.g., improved quality, reduced medical errors), organisational outcomes (e.g., financial and operational benefits), and societal outcomes (e.g., improved ability to conduct research, improved population health, reduced costs)”. In addition, in their review of implementations of EHRs around the world, Nguyen et al. (2014) concluded that EHRs “aid patient care and clinical documentation; for example, in improved documentation quality, increased administration efficiency, as well as better quality, safety and coordination of care.” The study by King et al. (2014) assessing physicians’ use of EHRs in the US, found that: “Most physicians with EHRs reported EHR use enhanced patient care overall (78 percent), helped them access a patient’s chart remotely (81 percent), and alerted them to a potential medication error (65 percent) and critical lab values (62 percent). Between 30 and 50 percent of physicians reported that EHR use was associated with clinical benefits related to providing recommended care, ordering appropriate tests, and facilitating patient communication”.

In sub-Saharan Africa, a study investigating the use of EHRs found that “91% reported use of Open Source healthcare software, with OpenMRS being the most widely used. Most reports were from HIV-related health centres.” In addition, the study investigated the barriers to the adoption of EHRs and found a “high cost of procurement and maintenance, poor network infrastructure and lack of comfort among health workers with electronic medical records” (Akanbi et al., 2012) are among the most commonly reported barriers.
Teleconsultation systems have been reported “to result in change in treatment plan, referral or evacuation rate, change in diagnosis, educational effects, and rapid decision making” (Deldar et al., 2016).

Telemedicine systems can be used to address a variety of health conditions including HIV/AIDS, TB, malaria, and chronic diseases (e.g. asthma, diabetes, heart failure, and hypertension), and in various contexts, including emergency rooms and pre-hospital care. For example, a review of 38 articles discussing telemedicine applications in emergency rooms (ERs) found that “11 studies focused on telemedicine for diffuse patient populations that typically present in ERs, 8 studies considered telemedicine in the context of minor treatment clinics for patients presenting with minor injuries or illnesses, and 19 studies focused on the use of telemedicine to connect providers in ERs to medical specialists for consultations on patients with specific conditions” (Ward, Jaana, & Natafgi, 2014).

The benefits of telemedicine systems include reductions in the use of service (e.g. hospital admissions/re-admissions), reductions in the length of hospital stay, and a decline in emergency department visits (Bashshur et al., 2014). In addition, a review of telemedicine applications in pre-hospital care, by Amadi-Obi et al. (2014), found that: “A majority of the studies [25/39] were on stroke management. The studies suggested that overall, telemedicine had a positive impact on emergency medical care. It improved the pre-hospital diagnosis of stroke and myocardial infarction and enhanced the supervision of delivery of tissue thromboplasminogen activator in acute ischaemic stroke.” Furthermore, a systematic review and meta-analysis of RCTs assessing the impact of telemedicine interventions found that telemedicine systems for diabetes patients were “associated with a statistically significant and clinically relevant absolute decline in HbA1c [hemoglobin A1c] level compared to control” (Marcolino, Maia, Alkmim, Boersma, & Ribeiro, 2013). In rural settings, according to findings by Marcin et al. (2016), telemedicine “can significantly improve provider, patient, and family satisfaction, increase measures of quality of care and patient safety, and reduce overall costs of care”.

Telemonitoring systems focusing on the primary care management of cardiovascular disease can “contribute to significant reductions in blood pressure, decreased all-cause and HF [heart failure] related hospitalisations, reduced all-cause mortality and improved quality of life. Telemonitoring was also demonstrated to reduce health care costs and appears acceptable to patients” (Purcell, McInnes, & Halcomb, 2014).
2.5 eHealth in developing countries
The current state of the literature on eHealth in developing countries has largely consisted of articles describing single uses of technology in healthcare delivery, as well as theoretical discussions and recommendations surrounding the implementation of eHealth-based interventions and policies (Crean, 2010; Gerber, Olazabal, Brown, & Pablos-Mendez, 2010).

In a study by Lewis, Synowiec, Lagomarsino, & Schweitzer (2012) in 16 LMICs, surveying how ICT is being used in the private health sector, the researchers found that “42% use it to extend geographic access to health care, 38% to improve data management and 31% to facilitate communication between patients and physicians outside the physician’s office. Other purposes include improving diagnosis and treatment (17%), mitigating fraud and abuse (8%) and streamlining financial transactions (4%)” (Lewis et al., 2012).

The areas of application vary. A systematic review of evaluations of eHealth implementation in developing countries by Blaya et al. (2010) found 45 articles put into eight categories: electronic health records; laboratory information management systems; pharmacy information systems; patient registration or scheduling systems; monitoring, evaluation, and patient tracking systems; clinical decision support systems; patient reminder systems, and research/data collection systems (Blaya et al., 2010). This study also found that eHealth systems improve communication between institutions, assist in ordering and managing medications, and help monitor and detect patients who might abandon care (ibid.).

The review by Blaya et al. (2008) of 56 articles evaluating eHealth implementations in developing countries suggests that the following functions have a positive impact (Blaya et al. 2008, p.16):

- Ability to track patients through the treatment initiation process, monitor adherence, and detect those at risk of not following up;
- Tools to decrease the communication times of information within and between institutions;
- Tools to label or register samples and patients;
- Ability to electronically monitor and remind patients of their responsibilities;
- Collection of clinical or research data using PDA;
- Reductions in errors in laboratory and medication data.
The power of eHealth has enabled health workers in remote areas to combat a variety of health conditions, including HIV/AIDS, as well as chronic diseases such as diabetes, asthma, and TB. For example, in Rwanda, health workers who ensure that HIV/AIDS patients take their medication sent information to other workers at the national health ministry, and that information was used to look for ways to improve medication adherence (Dentzer, 2010).

Even though eHealth interventions are increasing, there are many challenges that impede full implementations or scale-ups. A study in Ghana by Bedeley & Palvia (2014) found that, among the top five issues identified, the lack of (ICT) infrastructure is ranked as the highest issue, deemed as being very dear to the hearts of both consumers and providers. The remaining four issues include the lack of basic knowledge in ICT; the internet; financial and sustainability issues and privacy/security. Other studies have also revealed the following barriers and challenges to eHealth implementation in sub-Saharan and other LMIC regions (Fernández-Alemán, Señor, Lozoya, & Toval, 2013; Jawhari, Ludwick, Keenan, Zakus, & Hayward, 2016; Lewis et al., 2012; Were & Meslin, 2011):

- lack of clinical trials;
- a tendency to report positive impacts;
- infrastructural barriers such as reliable electricity, connectivity and networking capabilities;
- human resource barriers such as high staff turnover, absence of local technical support and low levels of computer literacy;
- organisational barriers such as a lack of local information system leadership or coexistence of multiple co-deployed systems without coordinated leadership;
- limitations of the currently available eHealth systems such as bugs, missing features and poor performance contributing to user resistance;
- a lack of ethically grounded eHealth policies or policies that appropriately address security and privacy issues.

2.6 mHealth

The term mHealth is relatively new for medical and public health practices (Goel, Bhatnagar, Sharma, & Singh, 2013). The term can be thought of as a subset of eHealth, focusing on the use of mobile devices (Wittet, 2012).
The Global Observatory for eHealth, cited by the WHO, defines mHealth as the use in “medical and public health practices of mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices” (WHO 2011, p.6).

mHealth involves the use of a range of mobile devices’ core functions, such as voice, SMS, and multimedia messaging services (MMS) as well as more complex functionalities and applications including general packet radio service (GPRS), third and fourth generation mobile telecommunications (3G and 4G systems), global positioning system (GPS), and Bluetooth technology (WHO, 2011). In addition to the importance of using small devices, such as a telephone that is carried around by patients, an important factor is that the mobile networks bring internet connectivity to huge areas where there are no wired networks available. This is particularly important in developing countries where relatively large healthcare facilities with several computers also get network connectivity through the mobile operators.

There is considerable enthusiasm for mHealth interventions – targeting both healthcare professionals and citizens/patients as users of the mobile devices – and “it has been argued that there is huge potential for mobile-health interventions to have beneficial effects on health and health service delivery processes, especially in resource-poor settings” (Vital Wave Consulting, 2009 cited by Free et al. 2013). This is especially true when these interventions are designed to provide support and services to health care providers (such as education, support in diagnosis or patient management) or target communication between health care providers and patients (such as appointment and medication reminders and test results notification) (Carey, Klotz, & Kenny, 2015; Free et al., 2013).

Around the definitions of eHealth and mHealth, there are basically similar attributes. For example, eHealth and mHealth can be defined as “the use of emerging information and communication technology, especially the Internet, to improve or enable health and health care” (Eng, 2001) and “mobile computing, medical sensor, and communications technologies for health care” (Istepanian, Jovanov, & Zhang, 2008), respectively. Thus, eHealth and mHealth facilitate the provision of healthcare through ICT (Ahmed et al., 2014).

### 2.7 mHealth opportunities and applications

In 2016, there were 7.9 billion mobile cellular subscriptions worldwide and 4.8 billion unique subscribers, up from 738 million in 2000 (GSMA, 2017; ITU, 2015). By 2020, it is estimated that the numbers will rise to 9.7 billion
mobile cellular subscriptions and 5.7 billion unique subscribers (GSMA, 2017). The real-life availability of mobile phones in populations is also impressively high, and regional forecasts of subscriber penetration rates from 2016 to 2020, range from 44% to 50% in Sub-Saharan Africa and from 84% to 87% in Europe (ibid).

The number of internet users worldwide has grown from 400 million in 2000 to 3.5 billion in 2016. The increase is higher for developing countries: from 100 million to 2.5 billion (ITU, 2015, 2016). In 2015, of the 940 million people living in LDCs, only 89 million (9.5%) used the internet, compared to 15.2% by 2016 (ibid.). In developing countries and LDCs, mobile-broadband subscribers have grown from 39% and 12% in 2015 to 41% and 19% in 2016 respectively (ibid.).

These figures show that the popularity of mobile technology has led to high and increasing ownership of the devices, which increases the opportunities for mHealth interventions to be delivered to large numbers of people. According to Akter et al. (2013), the unique attributes of mHealth that make it distinctive from other healthcare paradigms are:

- Accessibility: mHealth provides ubiquitous, universal and in unison accessibility for anytime, anywhere solutions;
- Personalised solutions: mHealth provides individualised solutions to address the specific needs of a specific person based on his/her profile;
- Immediacy: mHealth provides right-time services focusing on relevant, targeted and timely information;
- Location-based information: mHealth provides context-specific information services using GPS and cell of origin technology;
- Interactivity: mHealth creates value co-creation through long-term and more intense two-way interaction, and
- Mobility: mHealth serves the needs for temporal, spatial and contextual mobility.

The WHO (2011), surveyed 14 mHealth services in 114 countries – including decision support systems, awareness raising, surveillance, health surveys, patient monitoring, information, patient records, treatment compliance, community mobilisation, appointments reminders, mobile telemedicine, emergencies, toll-free emergency, and health call centres – and found that health survey (26%), surveillance (26%), awareness raising (23%) and
decision support systems (19%) were the most frequently reported. This survey shows that there is a growing use of mHealth.

Labrique et al. (2013) developed a framework that lays out 12 common mHealth applications used in health systems to strengthen innovations across various health programmes. Table 2.2 shows the 12 common mHealth applications. Descriptions are adapted from Labrique et al. (2013).

Table 2.2: The 12 common mHealth types of applications

<table>
<thead>
<tr>
<th>mHealth application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client education and behaviour change comm.</td>
<td>Applications focusing on clients and communication with mobile subscribers, delivering content intended to improve their knowledge, modify their attitudes and/or change their behaviour. Frequently used mobile phone functions include SMS, MMS, IVR, voice communication, video clips and images.</td>
</tr>
<tr>
<td>Sensors and vital point-of-care diagnostics</td>
<td>Applications that use novel sensors and technologies developed to conduct, store, transmit, and evaluate diagnostic tests through mobile phones. Frequently used mobile phone functions include the mobile phone camera, tethered accessory sensors and built-in accelerometers.</td>
</tr>
<tr>
<td>Registries and vital events tracking</td>
<td>Applications built to facilitate the identification and enumeration of clients for specific services, such as pregnancy and birth, and for tracking individuals with specific health conditions. Frequently used mobile phone functions are SMS, voice communication and digital forms.</td>
</tr>
<tr>
<td>Data collection and reporting</td>
<td>Applications used by frontline workers and health systems to facilitate the near-instantaneous collection and reporting of survey or patient data. Frequently used mobile phone functions are SMS, voice communication and digital forms.</td>
</tr>
<tr>
<td>Electronic health records</td>
<td>Applications developed for “back office” or central health care information technology systems allowing for access by and integration with mHealth applications. Such applications often tie in to regional, national, or global systems. Frequently used mobile phone functions are digital forms and mobile web (WAP/GPRS).</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
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<tr>
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</tr>
<tr>
<td>Electronic decision support</td>
<td>Applications designed to ensure providers' adherence to protocols or defined guidelines. Such systems incorporate automated algorithm- or rule-based instructions to help ensure quality of care. Mobile web (WAP/GPRS), store information “apps” and IVR are the most commonly used mobile phone functions.</td>
</tr>
<tr>
<td>Provider-to-provider communication</td>
<td>Applications that use a mobile phone to coordinate care and provide expert assistance to health staff. Frequently used mobile phone functions are voice communication, SMS, MMS and the mobile phone camera.</td>
</tr>
<tr>
<td>Provider work planning and scheduling</td>
<td>Applications to help health care workers plan and schedule their activities. Interactive electronic client lists, SMS alerts, and the mobile phone calendar, are the most commonly used mobile phone functions.</td>
</tr>
<tr>
<td>Provider training and education</td>
<td>Applications to provide continued training support to frontline and remote health care providers, through access to educational videos, informational messages, and interactive exercises that reinforce skills provided during in-person training.</td>
</tr>
<tr>
<td>Human resource management</td>
<td>Applications that use web-based dashboards and GPS tracking services to track the performance of community health workers (CHW). Voice communication and SMS are also used to communicate with CHW as they perform their field activity.</td>
</tr>
<tr>
<td>Supply chain management</td>
<td>mHealth tools to track and manage stocks and supplies of essential commodities. Web-based supply dashboards, GPS, digital forms and SMS are frequently used as ways of communication.</td>
</tr>
<tr>
<td>Financial transactions and incentives</td>
<td>Mobile-based financial transactions to pay for health care, transport, supplies or drugs, or to improve the deployment and scalability of incentive schemes.</td>
</tr>
</tbody>
</table>

Abbreviations: SMS, Short Message Service; MMS, Multimedia Messaging Service; IVR, Interactive Voice Response, WAP, Wireless Application Protocol; GPRS, General Packet Radio Service; GPS, Global Positioning Service.

Extensive reviews of mHealth research identified the use of mobile phone applications in a variety of areas: asthma, diabetes, mental health, smoking...
cessation, cancer, HIV/AIDS, tuberculosis, heart disease, cystic fibrosis, physical activity, safe sex, sexually transmitted disease, weight loss, chronic disease, brain injury, and eating disorders (Fiordelli, Diviani, & Schulz, 2013; Nhavoto & Grönlund, 2014). The overwhelming majority of the papers report positive results, and most concern developed countries (Nhavoto & Grönlund, 2014).

2.8 mHealth in developing countries

Developing countries are experiencing an unprecedented increase in the numbers of users of mobile technologies and internet technologies, as well as a decline in the price of devices and services (Aker & Mbiti, 2010; GSMA, 2017; ITU, 2015). As a result, many health programme implementers and policy-makers are exploring the extent to which mHealth can help address the challenges faced by the resource-constrained health system in terms of the availability, quality and financing of health care (Lewis et al., 2012).

This increase in interest is evidenced by the growing number of events included in the literature focused on mHealth. For instance, a report by Vital Wave Consulting (2009) showed that by 2009 there were 51 mHealth programs under operation in 26 developing countries around the world. According to the report, in developing countries the key mHealth applications are:

- Education and awareness;
- Remote data collection;
- Remote monitoring;
- Communication and training for healthcare workers;
- Disease and epidemic outbreak tracking, and
- Diagnostic and treatment support.

Other examples include the use for mobile technologies for (WHO, 2012):

- Data collection for surveillance and public health (e.g. outbreak investigation);
- Real-time monitoring of an individual’s health;
- Treatment support, health advice and medication compliance;
- Health information for practitioners, researchers and patients;
- Health education and awareness programmes;
- Diagnostic and treatment support, communication for health-care workers.
A review of mHealth research (63 articles comprising 53 studies) in developing countries reveals that mHealth studies “tend to concentrate on specific stages, principally on pilot projects that adopt a deterministic approach to technological inputs ($n=32$), namely introduction and implementation. Somewhat less studied were research designs that demonstrate evidence of outputs ($n=15$), such as improvements in healthcare processes and public health indicators. The review finds a lack of emphasis on studies that provide theoretical understanding ($n=6$) of adoption and appropriation of technological introduction that produces measurable health outcomes” (Chib et al., 2015). This review sort to categorise mHealth studies into data collection ($n=11$), consultation between health workers ($n=11$), appointment reminders for health workers ($n=1$), health promotion ($n=7$), medication reminders ($n=7$), appointment reminders ($n=7$), health information for patients ($n=5$), and test reminders ($n=2$).

A literature survey of 15 studies conducted in 13 developing countries in Europe, Africa, Latin and South America and Asia found that eleven studies reported significant positive effects of an e- & mHealth intervention on physical activity and/or diet behaviour (Müller, Alley, Schoeppe, & Vandelanotte, 2016).

The distribution of mHealth programs by location shows that India, South Africa, Uganda, Peru, Kenya, Tanzania, Bangladesh and Rwanda stand out for their level of mHealth activity (Chegona, Nyemba-Mudenda, & Metfula, 2013; Chib et al., 2015). A full investigation into the reasons for the higher prevalence of mHealth programs in some countries compared to others has not yet been assessed by the literature.

mHealth interventions are applied in maternal and child health and programmes reducing the burden of diseases linked with poverty, including HIV/AIDS, malaria, TB, diabetes, asthma, hypertension, and cardiovascular diseases (Bediang et al., 2014; Stephani et al., 2016; WHO, 2011).

In terms of effectiveness, the evidence is still insufficient (Agarwal, Perry, Long, & Labrique, 2015). mHealth applications have been shown to improve maternal care, improve communication with providers, decrease travel times, improve the ability to receive expert advice, cause changes in clinical outcomes, improve the promptness of data collection, reduce error rates and improve data completeness, as well as improving the adherence of frontline health workers to treatment algorithms (Agarwal et al., 2015; Hurt, Walker, Campbell, & Egede, 2016; Stephani et al., 2016). For instance, in Ethiopia, healthcare workers with minimal training, supervision,
and no incentives were able to use electronic forms on smartphones for patient assessment and routine data collection appropriately and accurately with only minor errors (Medhanyie et al., 2017).

2.9 Toolkits for mHealth

The declining cost of computers and mobile devices and their increasing capabilities offer strategic opportunities for integrated health delivery. Many professionals, including health administrators and technology developers, have started combining technologies based on the environments where they are used (Mechael 2008). For example, Cell-Life, a non-profit organisation that provides technology-based solutions for the management of HIV and AIDS and other infectious diseases such as TB, has developed innovative software that combines the use of mobile phones, the internet and computers in various locations, allowing pharmacists in better-equipped clinics to package drugs for rural clinics that do not have a pharmacist (Mechael & Daniela 2008). Similarly, the Millennium Villages Project, which operates in ten countries in Africa, including Mozambique, is integrating mobile technologies into its work as part of a broad-based mHealth initiative in partnership with key stakeholders (e.g. the MoH, mobile operators, research institutes, funding agencies); “it aims to extend existing eHealth systems to support the work of community health workers and facility-based staff to achieve the MDGs for health from the ground up” (Mechael 2008).

In May 2009, a consortium of Open Source developers and programme implementers, including Cell-Life, the Millennium Villages Project, Dimagi, D-Tree, MobileActive, InSTEDD, TextToChange, Ushahidi and UNICEF, was formed to build a set of platforms at no cost and with no restrictions in order to better serve the health needs of the poorest and most disenfranchised citizens in the world (Jackson, 2009). The consortium brought together a number of mobile technology tools for collaboration and sharing, including (Jackson, 2009):

- CommCare: a mobile-phone based application that allows community health workers to provide better, more efficient care and improve the coordination of community health programs;
- Mobilisr: an open source enterprise-class mobile messaging platform for NGOs around the world;
• Mesh4X: a platform for seamless cross-organisational information sharing between mobile devices, databases, desktop applications, and websites;
• RapidSMS: an open source platform allowing any mobile phone to use SMS to collect data, used in Malawi, Ethiopia and Nigeria to collect information and provide rapid feedback to field workers;
• GeoChat: a flexible open source group communications tool that enables mobile field communications and situational awareness during emergencies;
• Ushahidi: a web-based platform that any person or organisation can use to set up their own way of collecting and visualising information.

The focus of this consortium goes beyond health to all aspects of social development in developing countries.

In Ghana, the Mobile Technology for Community Health (MoTeCH), an open source platform for mHealth solutions, “adapts and integrates existing software applications for mobile data collection, electronic medical records, and interactive voice response to bridge health information gaps in rural Africa. MoTeCH calculates the upcoming schedule of care for each client and, when care is due, notifies the client and community health workers responsible for that client. MoTeCH also automates the aggregation of health status and health service delivery information for routine reports.” (MacLeod, Phillips, Stone, Walji, & Awoonor-Williams, 2012). MoTeCH integrates both mobile technology-based features (e.g. SMS, IVR) and external health systems (e.g. CommCare HQ, OpenMRS). CommCare HQ is a “general platform for mobile data collection that allows the creation of forms and questionnaires that use mobile data as input. The platform helps with application creation and deployment, as well as managing the collected data.” (Budhraja et al., 2013). OpenMRS is a “configurable open source electronic medical record application developed and maintained by a large network of open source developers coordinated by the Regenstrief Institute and Partners in Health and mainly used for HIV patient and treatment information management in Africa” (Seebregts et al., 2009). OpenMRS was first implemented in Kenya, and is in use in over 21 developing countries (mostly in Africa), including Mozambique (Chavez & Kovarik, 2017).
3. Research Settings and Context

In this chapter, I present the context and setting of the research. This presentation focuses on the context of Mozambique, where the study was conducted. Mozambique is a LDC. This chapter is organised as follows: in section 3.1, I will present the common features of LDCs. In section 3.2, I outline the political history and geography of Mozambique. In section 3.3, I present the population, social and economic status of Mozambique, and in section 3.4, the national health system and the HIS in Mozambique. In section 3.5, I will present the roles of vertical healthcare programmes, followed by eHealth and mHealth interventions in section 3.6. I conclude this chapter with a description of the fieldwork sites, in section 3.7, and the SMSaúde project, in section 3.8.

3.1 Common features of LDCs

Currently there are 48 LDCs of which the majority (34) are African, with a large population. Historical occupation by the European powers brought many changes which have influenced the current situation of postcolonial states. The magnitude of the direct and indirect consequences of colonialism are reflected in the current state-building processes, economic development, cultural norms, and social norms in these countries. Many LDCs, following the colonial era, have experienced a multitude of challenges including political instability and social and humanitarian issues. Despite the fact that many of these countries have abundant natural resources that include oil, gas and minerals, they remain among the poorest and most underdeveloped in the world.

These countries are in a state of dire poverty which is reflected in the low levels of per capita income (which indicates several financial constraints), the very small amounts of industrialisation in relation to production, and the low levels of education. Apart from these three main basic criteria, LDCs share the following problems:

- Predominance of subsistence activities with a low level of productivity, in particular food production;
- Limited manufacturing and an undiversified production structure (countries have a high export concentration and dependence on two or three primary commodities);
- Unsuitable and rudimentary economic infrastructure;
- Low level of education and an acute scarcity of skilled personnel;
• Weak and inappropriate public administration and governmental organisation;
• Rudimentary sanitary services, poor health and nutrition outcomes.

Major health challenges include:

• HIV/AIDS: In 2015, there were approximately 36.7 (34.0–39.8) million people living with HIV globally; Sub-Saharan Africa is the most affected region, with 25.6 (23.1–28.5) million people living with HIV (UNAIDS, 2016);
• Malaria: In 2015, most of the world’s malaria cases were accounted for in the African region (90%), followed by the South-East Asia region (7%) and the Eastern Mediterranean region (2%) (WHO, 2016c);
• Tuberculosis: Worldwide in 2015, there were an estimated 10.4 million incident TB cases, of which 11% of the cases were also HIV-positive; the highest proportion was in the African region, exceeding 50% in parts of southern Africa (WHO, 2016a);
• Malnutrition;
• Trichomoniasis: this is the most common sexually transmitted infection in poor communities in Sub-Saharan Africa and impoverished parts of Asia;
• High infant, child and maternal mortality;
• Poor sanitation.

Major challenges for the health systems include:

• Too few well-educated health professionals, many narrow specialties totally absent;
• Basic primary health services are performed by persons with little education in medicine;
• Unequal distribution of health professionals and services within the country;
• Bad infrastructure and low resources makes the transportation of patients less of an option;
• Many citizens/patients have to handle their health problems without professional help;
• Lack of access and affordability of preventive care.
3.2 Political history and geography of Mozambique

The history of Mozambique can be traced back to the 1st and 5th centuries AD, when Bantu-speaking people migrated from farther north and west. Swahili people, and later Arab people, established commercial posts along the coasts until the arrival of the Europeans. The first European explorer was Vasco da Gama in 1498. Portugal colonized Mozambique from 1505 until 1975, when Mozambique gained its independence. After two years of independence in 1978, the country erupted in civil war which lasted until 1992. In 1994, Mozambique held its first elections, in which Joaquim Chissano was elected President with 53% of the vote; 250 National Assembly members were voted in, with 129 deputies for the Liberation Front on Mozambique (FRELIMO) and 112 deputies for the Mozambican National Resistance (RENAMO), and nine representatives of the three smaller parties that formed the democratic Union (UD). FRELIMO has won all five elections since; Filipe Nyusi became the fourth President of Mozambique on 15 January 2015.

Mozambique is still significantly dependent on aid. External donors finance many sectors, including the health sector. The aid dependency is a legacy of the occupation and the 14 years of civil war.

Mozambique stretches for 2,470 km along Africa’s southeast coast and at 801,590 square km in total (Sweden is approx. two times smaller than Mozambique), it is the world’s 35th-largest country. Tanzania is to the north; Malawi, Zambia, and Zimbabwe to the west; the Indian Ocean to the east; and South Africa and Swaziland to the south (Figure 3.1). The map in Figure 3.1 shows Mozambique and the surrounding countries with the international borders (as described above), province boundaries (administratively, the country is divided into 11 provinces, including the capital of the country, Maputo City), the national capital, province capitals, major cities, main roads, railroads and airports. In total, the country has 128 districts, 33 municipalities, 36 towns and 405 administrative posts.
As of November 2016, the population of Mozambique was estimated to be 29,059,287 people, of which 51.3% are female and 48.7% male (Countrymeters, 2016). This is an increase of 30.4% (8,832,991 people) compared to the figure of 20,226,296 people that was based on the 2007 Mozambique census. Figures in 2015 show that there were 1,102,503 live births in Mozambique.
births and 325,645 deaths. The sex ratio of the total population was 0.95 (950 males per 1,000 females), which is lower than the global sex ratio of 1.02 (1,016 males per 1,000 females). As of November, 2016 the population density was 35.5 people per square metre.

The population age distribution, as of the beginning of 2016, was as follows: 45.9% of the population under the age of 15, 51.1% aged between 15–64, and 3.0% above the age of 65 (Countrymeters, 2016). Life expectancy (2016 estimate) is 51.8 years overall, and 51 and 52.6 years for men and women respectively. According to the UNESCO Institute for Statistics, 58.55% of the adult population are able to read and write, of which 73.26% are male and 45.37% are female; child literacy rates are 83.67% and 69.73% for male and female children (UNESCO, 2016). The population estimates explicitly take into account the effects of excess mortality due to HIV/AIDS and other diseases such as malaria and TB, which can result in lower life expectancy, higher infant mortality, higher death rates, lower population growth rates, and more changes in the distribution of population by age and sex than would otherwise be expected (Central Intelligence Agency, 2017).

The top five causes of mortality are HIV/AIDS (26.2%), lower respiratory infections (7.6%), malaria (5.6%), diarrhoeal diseases (4.8%), and TB (3.8%), representing 48% of the total deaths (2012 est.) (WHO, 2015a). Mozambique is prone to frequent outbreaks of vector-borne diseases such as cholera and dysentery. Malaria accounts for 29% of all deaths and 42% of deaths in children less than 5 years old (PMI, 2016). The estimated incidence rate of TB is 551 per 100,000 population (the figure includes HIV+TB) in 2015. The estimated TB incidence by age and sex (in thousands) is 7.4 for females between 0-14 years and 56 above 14 years; for males it is 7.4 between 0-14 years and 83 above 14 years (est. 2015) (WHO, 2016a). Mozambique ranks 19th among the 22 highest TB-burden countries in the world.

According to the current estimates, 1.5 million people live with HIV in Mozambique, and nearly 223 new infections and 108 deaths related to HIV occur per day (CNCS, 2016). The prevalence rate among adults aged between 15 and 49 is 11.5%. HIV/AIDS is the primary cause of death among adults and is the second highest cause of death (after malaria) among children. In Maputo, the adult HIV prevalence rate is 19.8% (male 19.5% vs. female 20%). The primary mode of transmission of HIV infection among adults is unprotected sex.

The government has engaged in an ambitious economic, social and political reform agenda, and has made efforts to consolidate macro-economic stability, as a result of which the country has recently experienced strong economic growth, averaging 7.4% in 2014.

3.4 The National Health System and HIS in Mozambique

The National Health System is a complex organisational system involving many actors, structured down from the central level (National) to province (Provincial Directorate of Health) to district (District Directorate of Health) and sub-district. This structure has been described as operating in an isolated top-down manner. Administratively, the Ministry of Health is divided into four major national directorates: the Directorate of Planning and Cooperation, the Directorate of Health, the Directorate of Human Resources and the Directorate of Administration and Management.

The Directorate of Administration and Management deals with all logistics, which include transport management, equipment, and supplies for surgical and laboratory purposes.

The Directorate of Health covers five departments responsible for providing public health delivery: the Department of Epidemiology and Endemics, the Department of Medical Assistance, the Department of Environmental Health, the Department of Community Health and the Pharmaceutical Department. Communicable diseases like sexually transmissible diseases/HIV/AIDS, TB, malaria, diarrhoeal diseases (including dysentery and cholera), acute respiratory infections and vaccine preventable diseases (e.g. measles, diphtheria, tetanus, poliomyelitis, rabies, etc.) are managed by the Department of Epidemiology and Endemics. Each of the disease programmes have their own budget (mainly supported by donor agencies), individual information systems and data flows in various channels. This department has a surveillance system called BES (“Bolentim Epidemiológico Semanal” in Portuguese, meaning Weekly Epidemiological Bulletin), which collects weekly epidemiological data on diseases such as HIV/AIDS, TB, and malaria, from all of the health facilities in the country. The Department of Community Health includes activities related to health prevention, treatment and promotion to the community, such as mental health, school and
adolescent health, reproductive health (Mother and Child Health Care Programme and Extended Programme for Immunisation), nutrition, and information, education and communication. While the Department of Environmental Health is responsible for hygiene, environmental health, and inspections in public facilities, including restaurants, hotels and commercial facilities, the Department of Pharmaceuticals is responsible for drug control, drug procurement, laboratories, logistics, and distribution.

The Directorate of Planning and Cooperation is responsible for planning, cooperation and health information. This directorate includes the Department of Health Information, which is the coordinating body of all statistics and the roles and maintenance involved in the HIS (SIS – “Sistema de Informação de Saúde” in Portuguese). The Department of Health Information collects monthly routine health-related data from district health facilities. SISPROG was the first national database-based system, developed in 1992. The data flow was from provincial capitals to the central hub using diskette. However due to its many limitations, SISPROG was replaced by the SIMP (Integrated System of Monitoring and Planning) which incorporated finances, healthcare workers, infrastructures and epidemiological surveillance. The low integration, storage and presentation of SIMP allowed MB-SIS (Módulo Básico SIS) to emerge. MB-SIS provides a consistent, simple and compatible application that was implemented across the whole country within the shortest possible space of time.

Healthcare services throughout the country are provided by the public National Health Service and complemented by the private sector with not-for-profit providers (mainly international and national NGOs) and for-profit providers (exclusively in main cities). The delivery of services is organised in five structures: traditional medicine and community health works; health post/facility and healthcare centres; rural and general district hospitals; provincial hospitals, and central and specialised hospitals. The first encounter with any kind of health care is usually through a network of traditional medical and community practitioners. Their role is to attend health care needs within a strong cultural, traditional and spiritual context. Health post/facility and health centre are generally the first points of entry, and the first contact between the health seeker and the health system. They provide essential curative and preventive services. The rural and general district hospitals offer services that include routine surgical interventions and include a diagnostic capacity, such as X-ray facilities. Specialised care is provided by the provincial hospital and sometimes by the Maputo central hospital.
3.5 The role of vertical healthcare programmes

During the civil war, the health sector was fragmented along vertical lines and emergency interventions were performed by external agencies and NGOs. Despite improvements, the MoH still depends on many multilateral partners such as the WHO, the United Nations Population Agency, the Joint United Nations Program for HIV/AIDS, UNICEF, World Bank, the United Nations Development Program, the African Development Bank, EU, the Organisation for Economic Cooperation and Development, and the Global Fund (WHO, 2016b). In addition, the list of bilateral partners includes the UK Department for International Development (DFID), the Japanese International Cooperation Agency and the Japanese Ministry of Foreign Affairs, the Norwegian Agency for Development Cooperation, the European Commission, Irish Aid, the Danish International Development Agency, the Direzione Generale Cooperazione Allo Sviluppo, Italian Ministry of Foreign Affairs, the US Agency for International Development (USAID), the German Organisation for Technical Cooperation and the German Ministry for Economic Cooperation (BMZ), the Netherlands, France, and the Flemish Department for Development Cooperation, plus several NGOs (ibid.) funded by some of the aforementioned partners.

Generally, before any funding negotiations between the MoH (specifically, the Cooperation Department) and the agency, the most important discussions take place within programmes (for example, HIV/AIDS, TB and malaria, within the National Directorate of Health for Communicable Diseases). Proposals are usually prepared elsewhere (usually outside the MoH) by cooperation agencies and NGOs, who mainly take the initiative in identifying intervention areas, and are only submitted for formal approval within the Cooperation Department that functions as a clearance body. Only very occasionally would the MoH prepare its own proposal to be submitted to the cooperation agencies for funding.

3.6 eHealth and mHealth in Mozambique

Various vertical programmes have been developed and various information systems implemented. For example, the Malaria Information System is a computerised system designed for the management and research of malaria data. This system was developed as part of the trilateral partnership between the governments of Mozambique, South Africa, and Swaziland. The
system was developed and installed across the country in partnership between an NGO, the Academy for Education Development (AED) and the MoH.

The system SIS-VE (MOZESS) was developed and implemented within the Mozambique Health Information Network (MHIN) project, through a collaborative partnership between the AED SATELLIFE Centre for Health Information Technology, the MoH, and the Mozambique Ministry of Science and Technology. This project aimed to strengthen the capacity of the MoH to collect, transmit and manage health data through the application of low-cost ICT.

The International Center for Aids Care and Treatment Programs (ICAP), part of the Mailman School of Public Health at Columbia University, developed and implemented the Electronic Patient Tracking System (EPTS or SESP – “Sistema Electrónico de Seguimento do Paciente” – in Portuguese) in collaboration with the MoH. The EPTS was implemented throughout the country and collects and manages HIV data. The development of this solution has been discontinued and now ICAP, the Elisabeth Glaser Paediatric AIDS Foundation (EGPAF) and the MoH have teamed up to develop and implement an OpenMRS system with country-specific configurations.

Absolute Return for Kids (ARK) – a United Kingdom-based international organisation whose purpose is to transform children’s lives – in collaboration with the MoH developed and implemented EPTS-TB, a system designed to collect and manage TB data.

The Mozambican Open Architecture Standards and Information Systems (MOASIS) organisation was created in 2008 and specialises in the field of HIS and maintaining the standards of eHealth. Its main objectives “are to support and strengthen the area of HIS and eHealth in the private, public and academic as well as to support the actions of donors in the HIS area and eHealth in Mozambique acting as independent and impartial mediator” (SANGONeT, 2015). MOASIS acts as a living lab and research organisation non-profit, affiliated with Eduardo Mondlane University and supported by Jembi Health Systems, based in Cape Town, South Africa (MOASIS, 2014). MOASIS is one of the largest programmes in the country, with more than twenty active projects including (Jembi, 2017):

- SIS-Compact Station: a fully embedded station composed of a touch screen micro-computer powered by embedded open-source software that enables the function of a pre-determined list of applications. Data in the system can be entered using a touch screen
computer, inputting data directly from the paper-based forms, or it can be uploaded through SD memory cards or transmitted by a short range radio system installed in the uData Capture Devices. Data can then be transferred to the upper levels (district, provincial and central) via email (including the use of 3G internet modems due to countrywide accessibility, the low cost and the quality of connection offered by the local network services – Vodacom or Movitel).

- **mICD-10**: a mobile phone application for quick consultation in the ICD-10 database. The ICD-10 database implementation began in 2006 and aims to classify diseases by mortality and morbidity.

- **uData Capture Device**: a low cost micro-data capture device for data capturing in remote health facilities in Mozambique. The device is a DIN A4 touch pad loaded with suitable firmware, in which data is entered by simply mounting the paper form over the uDCD touch pad and pressing (by hand or any pen or stylus) the appropriate areas on the paper.

- **SIS-MA – National M&E System**: a system that aggregates data from districts through provinces to the MoH, with the aim of supporting the collection, analysis, interpretation and continuous dissemination of the systematic health data that is used for the setting and monitoring of public health policies.

- **Information system for management of medicines and medical supplies (SI-MAM)**: A HIS that assists the MoH in the supply-chain management of medicines and medical supplies from central warehouses to hospitals and clinics.

The mHealth initiatives are described in Paper 5. Interventions have addressed a range of health conditions including HIV/AIDS, diarrhoeal diseases, malaria, nutritional deficiencies and TB. Applications include the use of SMS, voice, data for data collection and reporting, service use and supply management, client education and behaviour change communication, decision support, and financial transactions and incentives.

### 3.7 The SMSaúde project

The SMSaúde project was developed and implemented by ARK. The presence of ARK in Mozambique started in 2008 with a four-year programme
plan. Funding for the project was provided by DFID and USAID. ARK aimed to create a sustainable model of HIV care in Maputo province. The mission of ARK in Mozambique, in partnership with the MoH, was to improve access to quality HIV care and treatment, ensure adults and children adhere to their treatment, and follow-up on patients using cost-effective and innovative technologies (for example, point of care cluster of differentiation 4 [CD4] testing – in partnership with the Clinton Health Access Initiative [CHAI], and SMS reminders).

In 2011, ARK launched the SMSaúde project in partnership with the MoH, the mobile operator Vodacom Mozambique, and the University of Eduardo Mondlane. The SMSaúde project was a randomised control trial that used SMS technology in improving the adherence to HIV treatment. The project aimed to evaluate the impact of SMS reminders on adherence to antiretroviral therapy (ART). All SMS related costs were covered by Vodacom.

The project was launched in Maputo province across three health centres, enrolling 830 patients on ART during an 18-month trial. Patients received SMS appointment reminders and educational health messages.

While ARK’s successful four-year programme was formally handed over to the MoH in August 2012, ARK’s work in Mozambique with the SMSaúde programme continued through to May 2013. In May 2013, SMSaúde was scaled up in Gaza province, in partnership with the EGPAF and with ARK in a coordinating role. The scale-up extended the SMS model to patients with TB in Maputo. In Maputo, SMSaúde was implemented in four TB healthcare centres targeting around 500 patients. Funding for the scale-up for TB was provided by USAID. In Gaza, the implementation covered 16 healthcare centres and five mobile health clinics, and around 32,000 HIV patients were enrolled. The implementation in Gaza was funded by DFID.

3.8 Fieldwork sites

The fieldwork related to the SMSaúde project, was carried out in three healthcare centres for HIV and four healthcare centres for TB in Maputo province. For HIV, the healthcare centres were: Namaacha, Matola II and Machava II. For TB, the healthcare centres were: Machava II, Matola I, Matola II and Ndlavela. Namaacha and Ndlavela health centres are located in rural areas and the remaining health centres are located in suburban areas. These healthcare centres provide intense ART and TB care services.
Namaacha health centre is located in Namaacha village. Namaacha village is located in Namaacha district, in the southwest of Maputo province. The district borders with Matutuine district in the south, Moamba district in the north, Boane district in the east, and with Swaziland and South Africa in the west. According to the National Institute of Mozambique (INE), the projected population of Namaacha district is 52,340 (2016 est. projection), of which 50.9% (26,646) are female and 49.1% are male, all living in an area of 2,150 square km. The population density is 24.3 people/sq km (INE, 2010). The epidemiological situation of Namaacha district is dominated by diarrhoea, measles, dysentery, cholera and malaria. Namaacha health centre currently offers HIV/AIDS treatment and there has been an increase in cases of HIV-associated TB recently.

Matola I, Matola II, Machava II, and Ndlavela are located in Matola municipality in the province of Maputo. Matola is the largest suburban of Mozambique capital, Maputo city, and adjacent to it in the west. To the south of Matola is Maputo city and Boane district, Moamba in the north, Marracuene and Maputo city in the east and Boane in the west. According to the 2007 census, the population is 682,691 inhabitants, with a 2016 projected population increased of 279,384 (INE, 2010). The epidemiological situation in Matola is dominated by malaria, respiratory diseases (TB, pneumonia), diarrhoea and HIV/AIDS. The HIV seroprevalence rate is 20.7%. In relation to TB, 3,046 cases were reported, of which 1,487 were HIV-positive and 11 multi-resistant to treatment.
4. Research Design

This thesis is based on the design science research (DSR) approach. The DSR approach was used for designing and researching the artefact called SMSaúde. This chapter is dedicated to presenting the DSR approach. It starts with the scientific positioning of the research approach (section 4.1). Then, it presents the DSR principles and guidelines used as the foundation for carrying out the research (section 4.2). Motivations for my choice of DSR are presented and discussed in section 4.3. The subsequent section presents the discussion that explains my research in accordance with DSR (Section 4.4), and furthermore, it presents the overall design of my research.

4.1. Research framework

Design is fundamental to the information systems discipline (March & Storey, 2008), and a lot of focus is given to designing artefacts. There has been much discussion about how to define these artefacts, sometimes named the “IT artefact” (Benbasat & Zmud, 2003; Orlikowski & Iacono, 2001) and today, increasingly, the “IS artefact” (Lee, Thomas, & Baskerville, 2013, 2015). As regards the methods for the research-based design of IT or information systems artefacts, design science research has over the past decade grown to become a much-used method. DSR is based on design science or “The Sciences of the Artificial” (Simon, 1996).

Simon highlights that design is “concerned with how things ought to be, with devising art[e]facts to attain goals” (Simon 1996, p.114). He studied the design of “artificial things” or artefacts and has identified four indicia that distinguish the artificial from the natural, which can be used to set the boundaries for the science of the artificial (Simon 1996, p.5):

- Artificial things are synthesised (though not always, or usually with full forethought) by human beings.
- Artificial things may imitate the appearance of natural things while lacking, in one or many respects, the reality of the latter.
- Artificial things can be characterised in terms of functions, goals, adaptation.
- Artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives.

Simon’s view of artificial design is not only centred around problems of engineering. He argues that: “Everyone designs who devises courses of action aimed at changing existing situations into preferred ones” (p. 111).
This positioning is important because, as March & Storey (2008, p. 725) put it, “the development, implementation, use and management of information systems within organizational contexts are rooted in changing existing situations into preferred ones”. Such changes or designs are done with the aim of providing a practical perspective, starting with trying to fit technology into a complex socio-technical system in order to try to solve a problem that the participants perceive.

Simon’s ideas of design of “artificial things” are not only centred to artefacts that are technological. In fact, in their essay about the distinction between IT artefacts and information systems artefacts, Lee et al. (2015) found that Simon’s conception is not restricted only to IT artefact. They argue first, that Simon’s conception does not restrict artefacts only to IT artefacts. Second, even something made without ‘full forethought’ can be an artefact. Third, artefacts are not restricted to being something physical. Furthermore, Lee et al. (2015) define information systems artefacts as being constituted by three kinds of artefacts (technology artefact, information artefact and social artefact), which includes Simon’s terms of an IT artefact. The social aspect was also discussed by Simon. He stated that “every problem-solving effort must begin with creating a representation for the problem”, which he calls the “problem space”.

Simon’s discussions of the design activity of “artificial things” or artefacts makes a clear distinction between “natural science” and the “science of the artificial” or design science. According to Vaishnavi & Kuechler (2004), “a natural science is a body of knowledge about some class of things – objects or phenomenon – in the world (nature or society) that describes and explains how they behave and interact with each other. A science of the artificial (design science), on the other hand, is a body of knowledge about the design of artificial (man-made) objects and phenomena – art[e]facts – designed to meet certain desired goals”. Furthermore, Vaishnavi & Kuechler (2004) conclude that design science is “knowledge in the form of constructs, techniques and methods, models, well-developed theory […] – the know-how for creating art[e]facts that satisfy given sets of functional requirements. Design Science Research [DSR] is research that creates this type of missing knowledge using design, analysis, reflection, and abstraction”. A more simplified definition of DSR is offered by Hevner & Chatterjee (2010, p.5):

“Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of
innovative art[e]facts, thereby contributing new knowledge to the body of scientific evidence. The designed art[e]facts are both useful and fundamental in understanding that problem.”

This thesis uses the DSR which is regarded as a “problem solving paradigm” with the objective to “create innovations that define ideas, practices, technical capabilities, and product through the analysis, design, implementation, management, and use of information systems.” (Hevner et al., 2004) Through DSR knowledge and understanding of the problem to be solved are achieved. Therefore, the fundamental principle of DSR, as laid down by Hevner & Chatterjee (2010), is that “knowledge and understanding of a design and its solution are acquired in the building and application of an artefact” (ibid., p.5). The process of conducting and evaluating DSR is presented in the next sections where guidelines, as described by Hevner et al. (2004), are lined out in the context of this research.

4.2. Characteristics and scope of DSR

According to Hevner et al. (2004), information systems research, although dominated by the behavioural science approach, increasingly acknowledges DSR as a complementary approach. The authors define the design science paradigm as a paradigm that “seeks to extend the boundaries of human and organi[s]ational capabilities by creating new innovative artefacts” (Hevner et al., 2004, p. 75). The design process refers to a process of initiating something new (an artefact) in order to meet a social or organisational need. Design can be seen as the process in which design choices are made and visualised. A product is the end result of that process.

Within DSR, design is seen both as a process (a set of activities) and as a product (artefact) (Gregor & Jones, 2007; Walls, Widmeyer, & El Sawy, 1992). As they put it, “The term artefact is used to describe something that is artificial, or constructed by humans, as opposed to something that occurs naturally” (Gregor & Jones, 2007, p. 313), while the design process is defined as a sequence of expert activities that, with the help of an existing knowledge base, produces an innovative product (i.e., the design artefact) (Hevner et al., 2004)

DSR is a problem-solving paradigm (Hevner et al., 2004). This means that the environment, composed of people, (business) organisations, and technologies, together define the business need or ‘problem’ that the re-
The researcher aims to solve problems by creating an artefact. The created artefacts are evaluated with respect to the utility provided in solving those problems (Hevner et al., 2004).

Addressing business needs assures relevance in DSR (Hevner et al., 2004, p. 79), while rigour is achieved by appropriately applying the existing knowledge base. Applying the existing knowledge base means that the construction of the artefact relies on existing kernel theories that are applied, tested, modified, and extended through the experience, creativity, intuition, and problem-solving capabilities of the researcher (Markus, Majchrzak, & Gasser, 2002; Walls et al., 1992).

Knowledge and understanding in DSR are obtained through the construction of innovative artefacts that solve unsolved and important business problems (Hevner, et al., 2004, p. 84). DSR does not need to result in a complete artefact (Oates, 2006). On the contrary, artefacts constructed in DSR are rarely fully developed products that are used in practice. Instead, artefacts are innovations that define the ideas, practices, technical capabilities, and products (Hevner, et al., 2004).

The objective of DSR is to develop technology-based solutions for important and relevant business problems. Design science involves a rigorous process that includes designing the artefacts to solve observed problems, making research contributions, evaluating the designs, and communicating the results to the appropriate audiences (Hevner et al., 2004). Such artefacts, as stated by Hevner et al. (2004), can include four different types: concepts (vocabulary and symbols), models (abstractions), methods (algorithms and practices), and instantiations (implemented or prototype software). Artefacts may also include social innovations (van Aken, 2004) or new properties of technical, social, or informational resources (Järvinen, 2007); in short, this definition includes “any designed object with an embedded solution to an understood research problem” (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007).

Iivari & Venable (2009) define DSR “as a research activity that invents or builds new, innovative artefacts for solving problems or achieving improvements, i.e. DSR creates new means for achieving some general (unsituated) goal, as its major research contributions. Such new and innovative artefacts create a new reality, rather than explaining existing reality or helping to make sense of it”. According to Venable (2006), the core of DSR is “solution technology invention”.

Hevner et al. (2004) suggest that DSR should address either an unsolved problem in a unique and innovative way, or a solved problem in a more
effective or efficient way. They have presented a set of guidelines for DSR within the discipline of information systems. Their discussion of these guidelines is summarised in Table 3.1.

**Table 3.1. Design-Science Research Guidelines** (Hevner et al. 2004, p. 83)

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideline 1: Design as an Artefact</td>
<td>Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation.</td>
</tr>
<tr>
<td>Guideline 2: Problem Relevance</td>
<td>The objective of design science research is to develop technology-based solutions for important and relevant business problems.</td>
</tr>
<tr>
<td>Guideline 3: Design Evaluation</td>
<td>The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods.</td>
</tr>
<tr>
<td>Guideline 4: Research Contributions</td>
<td>Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies.</td>
</tr>
<tr>
<td>Guideline 5: Research Rigour</td>
<td>Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact.</td>
</tr>
<tr>
<td>Guideline 6: Design as a Search Process</td>
<td>The search for an effective artefact requires utilising the available means to reach the desired ends while satisfying the laws in the problem environment.</td>
</tr>
<tr>
<td>Guideline 7: Communication of Research</td>
<td>Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.</td>
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In summary, DSR requires the creation of an innovative, purposeful artefact for a special problem domain. The artefact must be evaluated in order to ensure its utility for the specified problem. Both the construction and evaluation of the artefact must be done rigorously, and the results of the research must be presented effectively both to technology-oriented and management-oriented audiences.
4.3. Choice of DSR for this study

The aim of this study, at least partially, is to develop an integrated system. The developed new artefact (the SMSaúde system) addresses an important technological problem (the lack of an integrated system for communication). Hence, the research method applied in this study is characterised as DSR (Gregor & Jones, 2007; Hevner et al., 2004). Another approach that also supports the development and design of real phenomenon, and which, thus, could be used as a method in this study, is Action Research (AR). AR aims to ‘solve current practical problems while expanding scientific knowledge’ (Baskerville & Myers, 2004).

I chose DSR, because as justified by Iivari & Venable (2009), “DSR assumes neither any specific client nor joint collaboration between researchers and the client”. My role as designer focused on building the artefact and making sure that all the necessary elements were incorporated. I initiated the interest in designing the artefact. I had my ideas explained to the organisation that implemented the solution. As described in Paper 2, defining the objectives of the artefact was done with the involvement of the people within the organisation. As Järvinen (2005) put it: “DSR is initiated by the researcher(s) interested in developing technological rules for a certain type of issue. Each individual case is primarily oriented at solving the local problem in close collaboration with the local people”. My objective of collaborating with people within the organisation was to make sure that they could buy into my ideas, and to ensure that the artefact could find its place with the organisation.

Järvinen (2007) points out that “design science solves construction problems (producing new innovations) and improvement problems (improving the performance of existing entities)” (ibid., p.51). It was my intention to produce an artefact that could be integrated with existing healthcare systems and work practices. In DSR, the objective is to invent a new, innovative artefact or solution technology to better address the client’s problem-solving interests (a socio-technical problem) (Järvinen, 2007); as such, I was motivated to design an artefact that could address social, organisational and technical aspects. One particular reason for this is that social and organisational factors tend to be overlooked in information system design and implementation, yet they often play the primary role in influencing whether health information technology solutions succeed or fail (Rice, 2004). Moreover, as in design science, “knowledge is generated, used and evaluated through the building action” (Järvinen 2007, p.50). Various iterations with
the people within the organisation led to various improvements of the artefact. Evaluations included looking at whether the artefact met specific organisational objectives, and whether the artefact was optimised sufficiently to be able to perform its tasks.

In DSR, the interest is also in evaluating the new information systems artefact in an organisational context (Iivari & Venable 2009). In this context, my evaluation of the information systems artefact was based on the use of mixed methods. Peffers & Rothenberger (2012) point out that the choice of evaluation methods is driven by the choice of artefact. They differentiate artefacts between algorithm, construct, framework, instantiation, method and model. Of the eight evaluation methods types (logical argument, expert evaluation, technical evaluation, subject-based experiment, action research, prototype, case study, and illustrative scenario), prototype – the implementation of an artefact aimed at demonstrating the utility or suitability of the artefact – and case study – the application of an artefact to a real-world situation, evaluating its effect on the real-world situation (Peffers et al., 2012) – were chosen as the evaluation methods. The other methods for the evaluation of the artefact include those within qualitative and quantitative approaches.

4.4. My research in accordance with DSR

The challenges of the development, deployment, and integration of mobile devices in healthcare information systems (e.g., numerous types of routine health information systems with different characteristics, numerous stakeholders, legal issues, limited capabilities of mobile networks) are significant and highly inter-correlated. In this thesis, various challenges are addressed through different phases of the performed research work, and in this section, the DSR framework is used to frame and describe the performed research process in a unified way.

Peffers et al (2007) proposed and developed a DSR methodology (DSRM) and their efforts contributed to information systems research by providing a commonly accepted framework for successfully carrying out DSR and a mental model for its presentation. The process consists of a nominal sequence of six steps (Peffers et al., 2007):

1) Problem identification and motivation,
2) Objectives of the solution,
3) Design and development,
4) Demonstration,
5) Evaluation, and
6) Communication.

These research process steps are used in the next section as a framework for presenting the performed research process. Geerts (2011) explained that activities such as Evaluation and Communication often result in revising the artefact’s objectives and design. Iteration is ingrained in DSR and Hevner et al. illustrate that with their build-and-evaluate loop: evaluation provides feedback information on the designed artefact and a better understanding of the problem, which leads to a re-iteration of the design process (Hevner et al., 2004).

4.4.1 Problem identification and motivation
Since DSR is a problem-solving paradigm (Hevner et al., 2004), it is very important to define and understand the business need or ‘problem’ that the designed artefact will solve.

The starting point for the development of the SMSaúde system was a practical problem experienced by a non-governmental organisation called Absolute Return for Kids (ARK). The problem was then analysed in relation to the existing literature within the information systems area. The problem was initially defined in the first phase of the first DSR cycle, but the practical experiences of designing, developing and implementing the SMSaúde system in real-life settings in the following DSR cycles resulted in a deeper understanding of the problem (Paper 2). This triggered a new literature review aiming to understand and explain the new aspects of the problem area. Therefore, at the beginning of each DSR cycle, the identification of and motivation for solving the problem were revisited based on the lessons learned from the demonstration and an updated literature review. The re-defining of the problem was also important, since the SMSaúde system was developed in two different contexts and the problem identified for the first context (SMSaúde for HIV) could differ from the needs in the other context (SMSaúde for TB).

4.4.2 Objectives of the solution
In this phase, the objectives for the SMSaúde system are formulated to address the needs identified in phase 1. The objectives are a set of requirements or goals that specify the type of the system and also define its scope and boundaries.
The requirements for the SMSaúde system are derived from phase 1, problem identification. The requirements for the SMSaúde system were re-analysed in each DSR cycle and were re-defined if there was such a need. The requirements were also re-defined according to the practical experiences of implementing the SMSaúde system in real-life settings and the lessons learned from the demonstration. The requirements formulated in this phase are general and describe what the SMSaúde system is for. The requirements are then, in phase 3, transformed into a set of design principles for the SMSaúde system.

In the initial phase of the research work conducted in this thesis, the main goal was to identify what is the most state-of-the-art use of mobile technologies to improve health care systems. For that, a literature survey was performed at the beginning of this research process (Paper 1). The goals of the survey were to

1) identify the geographical distribution of the publications on mobile technologies and geographical information systems (GIS);
2) investigate how mobile technologies and GIS have been used to improve health care, and
3) identify the effects associated with the use of mobile technologies and GIS.

The literature survey results were published in Paper 1 under the name “Mobile Technologies and Geographic Information Systems to Improve Health Care Systems: A Literature Review” (Nhavoto & Grönlund, 2014). The focus in this paper was on mobile technologies for healthcare, not GIS. The literature survey identified numerous interventions based on introducing mobile services in different healthcare areas, confirming the recognised potential of mobile healthcare services and the existence of business needs.

4.4.3 Design and development, demonstration and evaluation

The defined research objectives are addressed through the process of building and evaluating the key artefact, namely the SMSaúde system. Each of the main research objectives is addressed through a single information systems research process (or design cycle), described in the design science research framework using the following phases: Develop/Build and Justify/Evaluate. For different information systems research processes, different methodologies and foundations from the knowledge base for previous and related work were used to address the defined objectives. More descriptions and discussions of the specific methods used and contributions were gained
through the design and development, demonstration, and evaluation phases, and these are given in the next chapters. Each of the research processes are also described in detail in the research papers contained in this thesis.

4.5. Overall design of my research

The overall design of my research is presented in Table 4.2.

Table 4.2. Overall design of my research in accordance with DSR

<table>
<thead>
<tr>
<th>Phases</th>
<th>Research papers and research questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1. Problem identification and motivation</td>
<td>Paper 1 (RQ1), Paper 2 (RQ2)</td>
</tr>
<tr>
<td>Phase 2, 3 &amp; 4. Objectives of the solution, Design and Development, and Demonstration</td>
<td>Paper 2 (RQ2)</td>
</tr>
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</table>

4.5.1 Overall research in accordance with DSR

My research, as referred to in Section 4.1, follows the guidelines for design in information systems research by Hevner et al. (2004). Table 4.3 shows my research in accordance with the guidelines of DSR. In the table, the guidelines and descriptions are adapted from Hevner et al. (2004).

Table 4.3. My research in accordance with the guidelines of DSR

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Description</th>
<th>My research</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Design as an Artefact</td>
<td>Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation.</td>
<td>A web-based information system (SMSaúde) was developed at phases 2-4, as suggested by Peffers et al. (2007)</td>
</tr>
<tr>
<td>2. Problem Relevance</td>
<td>The objective of design-science research is to develop technology-based solutions to important and relevant business problems.</td>
<td>The construction of SMSaúde is a technology-based solution that is relevant to addressing identified problems. The SMSaúde artefact was integrated in healthcare services in various healthcare centres.</td>
</tr>
<tr>
<td>3. Design Evaluation</td>
<td>The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods.</td>
<td>The development of evaluation criteria was carried out throughout the entire research process. The criteria were constructed based on context-specific data, including both the analysis of qualitative and quantitative data.</td>
</tr>
</tbody>
</table>
| 4. Research Contributions | Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies. | The main contributions are:  
1) a systematic review of the utilisation of mobile technologies for improving healthcare services (Paper 1);  
2) an increased understanding of how mobile technologies can be designed, developed and implemented for specific healthcare services (Paper 2);  
3) an increased understanding of the effects of the use of an integrated mobile phone-based system in improving patients’ outcomes (Paper 3);  
4) an increased understanding of the perspectives of patients and healthcare workers on an integrated mobile phone-based system (Paper 4);  
4) an increased understanding of the applications, success/failure factors, challenges and policy implication of mHealth interventions in a resource-constrained country (Paper 5). |
<table>
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<tbody>
<tr>
<td>5. Research Rigour</td>
<td>Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact.</td>
<td>Rigorous methods have been applied in the construction of the artefact. The evaluation of the artefact has been documented in Paper 3, Paper 4, and Paper 5.</td>
</tr>
<tr>
<td>6. Design as a Search Process</td>
<td>The search for an effective artefact requires utilising the available means to reach the desired ends while satisfying the laws in the problem environment.</td>
<td>The search for an effective artefact was influenced by an identification of the design requirements and was followed by the construction of SMSaúde (Paper 2).</td>
</tr>
<tr>
<td>7. Communication of Research</td>
<td>Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.</td>
<td>The research findings have been communicated to both technology-oriented as well as management-oriented audiences (international conferences on health informatics; higher seminars, and international journals related to the mHealth and information systems research community).</td>
</tr>
</tbody>
</table>
5. Research Methods

This chapter describes the research methods used to collect and analyse the data in this study. The choice of methods in the thesis took into consideration the philosophical assumptions of DSR. In order to answer the overall research question (How can mobile technologies be effectively integrated with routine healthcare services?), both qualitative and quantitative research approaches were adopted. The key motivation for the choice of these approaches is that “the combination of both qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone [...] Qualitative data tends to be open-ended without predetermined responses while quantitative data usually includes closed-ended responses such as found on questionnaires or psychological instruments” (Creswell, 2013). In addition, Chib (2013) argues that an appropriate mix of quantitative and qualitative methodologies will better inform academics, particularly when investigating important issues such as relations within healthcare settings.

In qualitative research, there are a variety of methods of data collection, including observations, textual and visual analysis, and interviews (individual or group) (Silverman, 2013). In healthcare research, the most common methods used are interviews and focus groups (Britten, 1999; Legard, Keegan, & Ward, 2003). Interviews are of three types: structured, semi-structured and unstructured. Focus groups are similar to less structured interviews (Gill, Stewart, Treasure, & Chadwick, 2008), where a group discusses a particular topic in a way that is guided, monitored and recorded by a researcher (Bloor, Frankland, Thomas, & Robson, 2001).

In quantitative research, methods include questionnaires, and in healthcare research particularly, also the analysis of existing health records or case report forms including the results of laboratory essays and measurements specific to a scientific study.

5.1 Data collection

The data collection was carried out using the following methods:

- Literature review in Paper 1.
- Focus group and observations in Paper 2.
- Questionnaires and interviews in Papers 4 and 5.
5.1.1 Literature review

One good way of understanding a problem is investigating the existing discussions relating to the problem. This can be done by conducting a literature review, which was the first step in my research. Webster & Watson (2002, p. xiii) emphasise how “a review of prior, relevant literature is an essential feature of any academic project. An effective review creates a firm foundation for advancing knowledge. It facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed. In the information systems field, we see few published review articles. As a result, the progress of our field is impeded.” In essence, a literature review helps to uncover what is already known prior to initiating any research study (Järvinen 2008).

There are many reasons for conducting a literature review. For example, Levy & Ellis (2006) note that a literature review helps the researcher to (1) identify research gaps and shape the research direction, i.e., understanding what is already known, and building on existing knowledge to start new research; (2) provide a theoretical foundation for the research; (3) simplify a research problem using similar existing research; (4) justify the research contributions that the new work needs to make, as opposed to the contributions made by existing research; and (5) inform the formulation process of the research questions, methodology, and goals.

I used the literature review in Paper 1 to understand the research topic, scope and research gaps. The literature review was conducted between December 2012 and April 2013. It included studies published between 2005 and 2012. The literature identified the current research focus, the research gaps, and the effects associated with the use of mobile technologies and geographical information systems in health-related research for improving health care.

The research articles were systematically identified through a combination of computerised database searches and manual searches of the reference lists in the relevant articles found. The databases included were PubMed, BioMed Central, Scopus, Science Direct, and Web of Science. The search was done using the following keywords: cell phone, mobile phone, SMS, and text message, combined with health; and GIS combined with health. The search was restricted to the title and abstract fields, to avoid retrieving articles that were not focused on these topics yet still mentioned the terms. In addition, only publications in peer-reviewed journals and conference proceedings were selected.
The initial search yielded 3,376 articles which were screened for eligibility. A review of the titles and abstracts allowed the identification of 271 useful articles. These articles were further analysed and organised into categories. Six categories for mobile technologies and four categories for geographic information systems emerged.

In Paper 4, a broad literature scan was conducted of web-based portals, web databases, mHealth review documents and reports that specifically mapped mHealth initiatives in Mozambique. The web databases included Google Scholar, IEE Xplore, African Index Medicus (AIM), BioMed Central, PubMed Central, and the Public Library of Science. The aim of this literature scan was to systematise mHealth implementations in Mozambique. The various sources were searched using the following keywords: ‘Mozambique’ AND (‘eHealth’ OR ‘mHealth’ OR ‘electronic health’ OR ‘mobile health’ OR ‘e-health’ OR ‘m-health’ OR ‘health text message’ OR ‘health SMS’ OR ‘health mobile phone’ OR ‘PDA’ OR ‘health mobile communication’).

5.1.2 Focus group and observations
Focus groups and observations were used in the second study (Paper 2). In Paper 2, respondents were grouped into three categories: i.e., product owner team, design team and development team. The product owner team group included two of ARK’s staff (the project coordinator and project director) and the first author of the paper. The design team group included two computer experts and two medical doctors. The medical doctors were from ARK and the computer experts were from ARK and the Informatics Department at Örebro University. The development team group included three undergraduate students from the Informatics Department at Eduardo Mondlane University, and the two computer experts.

The medical doctors were researchers with strong clinical backgrounds and substantial experience in healthcare, plus transversal understandings of the problems faced by patients and healthcare workers. The students were selected because they had experience in software development.

The focus group discussions had different purposes. The first session between the product owner team groups aimed to formulate the objectives of the solutions. In this discussion, the first author presented and explained the initial version of the objectives of the solution. Then, the other members provided feedback and new formulations emerged. As new formulations emerged, the review circle continued until satisfactory solution objectives were achieved.
The second focus group discussion with the design team aimed to (1) discuss the system requirements as outlined in advance by the medical doctors, and (2) define the overall system requirements. The requirements were discussed using the brainstorm technique, and documented and elaborated in more detail as new ideas emerged.

The focus group discussion with the development team aimed at refining the general architecture of the system and discussing the programming steps. In addition, discussion meetings focused on testing the system prototypes and enhancements.

All of the focus group discussion sessions took 45 to 90 minutes and were recorded, transcribed and analysed. The presence of audio recording equipment was acknowledged by the moderator before the initiation of the discussion. The issues discussed were summarised by the moderator (the first author). The summaries were reviewed and agreed with the group of respondents.

Observations were done during the evaluation and demonstration steps. The participant observations that took place during the evaluation step aimed at gathering data about how the system was set up in the testing computer, and its performance against the quality attributes required. The quality attributes included testing for functionalities, completeness, consistency, accuracy, performance, reliability, and usability.

Participant observations during the demonstration step aimed at gathering data about how the system was set up in the user computer (the remote computer positioned at the healthcare centre) and how the user (the healthcare worker) used the system. Before the demonstration step, I visited the implementation sites and learnt about the healthcare workers who would be using the system. The data was recorded using interviews, field notes and reflexivity journals.

5.1.3 Electronic medical record review

Patient data for people with HIV were routinely collected and fed into the EPTS-HIV. The EPTS-HIV is a Microsoft Access-based system containing the demographic, clinical and pharmaceutical data of patients enrolled in HIV care. To ensure data quality, particularly for the SMSaúde project, the electronic database contained rules for validating the input data (e.g. maximum and minimum limits on numerous variables). Data from all the study sites were incorporated into a central database located at ARK’s headquarters in Maputo. The central database was used to monitor data quality and for the regular monitoring of the study.
Demographic variables (e.g. sex, age, residence, marital status) and clinical variables (weight, height, WHO stage, CD4 absolute counts), the date of last drug pickup, and the defaulting status at the end of 12 months were abstracted from the electronic patient database. These data were used in Paper 3.

The SMSaúde trial recruited 830 HIV-positive people, and randomised them on a 1:1 basis into receiving the SMS text messages (the intervention group) or standard care (the control group). These patients were recruited from three healthcare centres in Maputo, namely Machava II, Matola II and Namaacha. The patients were followed between November 2011 and March 2012.

### 5.1.4 Questionnaires

Four questionnaires were designed. The process of the design of each questionnaire followed these steps:

1) **Draft questions**: I drafted the ideas for questions and had other co-authors comment and suggest amendments. Drafting the questions was aligned to the purpose of the study and the types of participants invited.

2) **Sequence the questions**: I arranged the questions with care. I started by placing the general questions and then the key questions in a logical sequence. Then, I went backwards to develop additional questions. In this way, I could think about the questions that might immediately proceed the key questions. I did this in a way that the questions and topics should lead to a logical and natural flow to the conversation.

3) **Phrase the questions**: I examined the list of questions by identifying those questions that seemed important to the study and edited them in a way that they could be used, for instance, as open-ended questions or closed-ended questions. While doing this, I kept the questions simple because this type of question, as argued by Krueger & Casey (2015), “gets the participant to bring shape and form to the discussion. It pulls out assumptions and lays bare core principles”.

4) **Estimate the time for each question and for the entire interview/discussion**: I estimated how much time should be spent on each question. Estimating the time for the questions took into consideration the complexity of the question, the category of the question (e.g.,
open or closed) and the way the questionnaire was being answered (e.g. on-site interview, telephone interview or online, via Skype). Typically, closed-ended questions had a shorter answer time – usually less than two minutes – and open-ended questions took two or three minutes. Questions for focus group discussion took more time, about five-ten minutes. This estimation was aggregated and the overall time for the entire interview/discussion was estimated.

5) Get feedback from others: I shared the results from step (4) with the co-authors for review.

6) Test the questions: I tested the questionnaire with a sample of participants who later on were not part of the study. The aim of the test was to (a) get the feeling of how the question sounded, (b) to see if the questions confused the participants, and (c) to check if the participant had understood the intent of the questions. Any issues that emerged during the testing step were addressed before the actual data collection.

The first two questionnaires were designed and fed into Paper 4. These two questionnaires were administrated to patients and healthcare workers in five healthcare centres in Maputo. The healthcare centres provide intense HIV and TB care. The selection of patients was based on the following criteria: (1) they participated in the SMSaúde trial in HIV and TB care, and (2) they received the SMS messages. In addition, TB patients who had abandoned treatment, were cured, or had completed their treatment were included. For HIV patients, those who were still in treatment or had abandoned the treatment were included. With these criteria, the search in the patient database yielded 404 eligible participants (248 patients living with HIV and 156 TB patients). Due to various factors including offline phone numbers, incorrect phone numbers, and those who were contacted with no response, 141 patients agreed to take part and were given the questionnaire. The questionnaire for patients was composed of 27 questions that include socio-demographic characteristics, socio-economic characteristics, therapy or drug related information, social, and SMSaúde system-related variables.

Healthcare workers were recruited for participation if they had participated in the SMSaúde trial and had provided healthcare services to patients with HIV and/or TB. Forty healthcare workers were administered the questionnaire. The questionnaire for healthcare workers was composed of 13 questions and the majority were related to the SMSaúde system. The
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SMSaúde system-related variables included questions that explored participants’ perceptions of the system, including the ease of use, risks and benefits, and their intentions to reuse the system. Prior to this, the questionnaires were pilot tested with 19 participants (15 patients and four healthcare workers).

The last two questionnaires were designed and fed into Paper 5. These two questionnaires were administered to key informants who had participated in mHealth initiatives in Mozambique. The first questionnaire targeted people at the management level (e.g. government officials, project managers, project coordinators, IT managers, data managers, data supervisors, IT providers) and the second questionnaire targeted healthcare workers (e.g. healthcare technicians). The questionnaire for management personnel was composed of 43 questions mainly aiming to gather information about the project, intervention, success/failure factors and challenges. The questionnaire for healthcare workers was composed of 16 questions aiming to gather mainly information about the intervention, success/failure factors and challenges.

5.1.5 Interviews

In Paper 4, the interview data were collected through face-to-face and telephone interviews. The interviews with patients were conducted as telephone interviews while they were done face-to-face with healthcare workers. The interviews were guided by semi-structured questions (see annex 1 and annex 2 for the questionnaires). The number of patients interviewed was 141 (72 patients living with HIV and 69 TB patients). On-site interviews with healthcare workers were conducted in five healthcare centres in Maputo: Machava II (urban), Matola I (urban), Matola II (urban), Namaacha (rural), and Ndlavela (rural). Forty healthcare workers who had participated in the SMSaúde trial were interviewed (Table 5.1). The interviews took approximately 30 minutes.

<table>
<thead>
<tr>
<th>Healthcare worker’s occupation</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical technician</td>
<td>8</td>
</tr>
<tr>
<td>Data entry clerk</td>
<td>9</td>
</tr>
<tr>
<td>Health counsellor</td>
<td>10</td>
</tr>
<tr>
<td>Medical doctor</td>
<td>4</td>
</tr>
</tbody>
</table>
In Paper 5, the interviews were guided by semi-structured questions (see annex 3 and annex 4 for the questionnaires). Forty-four participants were interviewed (Table 5.2). Some interviews (11) were conducted face-to-face, over Skype (five) and the rest over the telephone (25). On-site interviews were conducted in the respondents’ workplaces; for instance, the interview with the government official was conducted at the Ministry of Health.

Table 5.2. List of participants in Paper 5

<table>
<thead>
<tr>
<th>Participant title</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government official</td>
<td>1</td>
</tr>
<tr>
<td>Project manager</td>
<td>13</td>
</tr>
<tr>
<td>Project coordinator</td>
<td>8</td>
</tr>
<tr>
<td>IT manager</td>
<td>2</td>
</tr>
<tr>
<td>Data supervisor</td>
<td>1</td>
</tr>
<tr>
<td>Data manager</td>
<td>1</td>
</tr>
<tr>
<td>IT provider</td>
<td>1</td>
</tr>
<tr>
<td>Data entry clerk</td>
<td>10</td>
</tr>
<tr>
<td>Health care technician</td>
<td>6</td>
</tr>
<tr>
<td>Healthcare trainer</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>45</strong></td>
</tr>
</tbody>
</table>

All of the interviews were conducted in Portuguese. The telephone and Skype interviews were voice recorded upon the respondent’s agreement. Notes were written for the interviews that were not voice recorded. Table 5.3 shows a summary of the data collection methods and sources.
Table 5.3. Summary of data collection methods

<table>
<thead>
<tr>
<th>Paper</th>
<th>Research methods</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Literature Review</td>
<td>Focus group</td>
<td>Observations</td>
<td>Questionnaires</td>
</tr>
<tr>
<td>Paper 1</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper 2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Paper 3</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper 4</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Paper 5</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

5.2 Data analysis

As I used different data collection methods, it follows that the data analysis was multipronged. Yin (2009, p. 127) points out that “data analysis consists of examining, categorising and tabulating, or otherwise recombining the evidence, to draw empirically based conclusions”. This concept, as suggested by Krueger & Casey (2015), should drive the analysis; they believe that the “analysis begins by going back to the intention of the study and survival requires a clear fix on the purpose of the study”. As part of making sense of the huge amount of information, Rabiee (2004) argues that “getting rid of extra and irrelevant information and travelling safely through the maze of large and complicated paths of information” is extremely helpful.

The first form of analysis I did was a literature analysis, because the literature review was the first step of data collection I employed. The literature review involved searching for research papers and doing the analysis with the aim of framing the research topic and discovering research gaps. The literature analysis used a two-step process by Levy & Ellis (2006): (1) identify the major concepts discussed in a literature text, and (2) place the concepts and citations in the correct category. In addition, I used the concept matrix method of literature review. This method, as Klopper et al. (2007, p. 1) outlined, could be used “at the beginning of a problem-based research project when the researcher’s knowledge about the subject is finite and her/his ignorance about it is more or less infinite”.

I used the concept matrix method to group the selected papers according to themes (concepts of discussions). The analysis process followed Webster & Watson’s (2002) concept matrix model and typically involved the following steps:
1) Search through the paper using the keywords. If the paper met the keywords, then;
2) Read the abstract. If the abstract was relevant to the topic, then;
3) Categorise the paper based on the aspects presented, then;
4) Read the list of references in the categorised article, then;
5) Find the paper(s) selected from the list of references, and apply steps 1 – 4 again.

For the qualitative data, I used qualitative analysis techniques with the aim of bringing meaning to information gathered using different data collection methods. Rabiee (2004) points out that, unlike quantitative analysis, qualitative analysis occurs concurrently with data collection. A helpful way of thinking when doing analysis of this type is to consider a continuum of analysis consisting of raw data, descriptive statements and interpretation (Krueger & Casey, 2015).

Descriptive analysis was used to analyse the data collected from the questionnaires, focus group discussions, observations and interviews. The data were summarised into categories with the aim of comparing different descriptions of the data obtained from these three data sources as a means of validation. In papers 4 and 5, analysis allowed the presentation of the categories of data in different ways such as via a table, providing a pictorial view of the data. The framework analysis used five key stages as outlined by Ritchie & Spencer (1994): familiarisation; identifying a thematic framework; indexing; charting; mapping and interpretation. Therefore, in general, the analytic manipulations of the data involved:

1) Content analysis to organise the data into different arrays;
2) Making a matrix of categories and coding variables, e.g. into categorical or ordinal data;
3) Examining the data using data displays (e.g. graphics) and tabulating the frequency of different events, and using descriptive statistics, such as frequency distributions, and/or performing statistical analysis;
4) Examining the complexity of tabulations and looking for statistical relationships among categories or variables;
5) Interpreting all the information generated and choosing the means of depiction for the data summary; for example, text or graphic representation.
I began the process of data analysis during the data collection as a way to facilitate the discussion and generate rich data from different sources, and then completed this with observational notes and recordings.

Step 1) basically involved reading the transcripts and seeking information that could be grouped together under a theme/category. I studied answers to a specific question to find common themes/categories that contributed to answering the question. When building the themes, I included illustrative quotations and associated them with key respondents. After establishing the key responses to each question, in step 2), I made a matrix of the themes/categories and coded the responses. In addition, I characterised the variable depending on the type of response given. For instance, I coded as ordinal variables questions that yielded numeric value answers. Afterwards, in step 3), I used descriptive statistics to represent the data. I used statistical measures too, for instance for information that represented the demographic and baseline data of participants, such as the mean or average value, median, quartiles for continuous variables (quantitative responses), and frequency and percent for categorical variables (qualitative responses).

In step 4), I analysed the information generated previously, looking for trends and relationships between the different sets of responses and themes/categories. For example, answers to one question could be related to the response to another question. With this analysis I also aimed to identify similarities and differences between respondents’ views. For example, in Paper 4, I looked at similarities and differences between patients’ and healthcare workers’ views on the SMSaúde system. In Paper 5, I identified similarities and differences between the views of the managerial staff and healthcare workers on mHealth interventions. The analysis for statistical relationships among the categories or variables involved using nonparametric methods (e.g. Man-Witney U test and Spearman’s Rho correlation test). In Paper 3, I also evaluated the statistical significance performing statistical tests such as the Kaplain-Meier test and z-test. I used Poisson methods and Cox proportional hazards models to evaluate the interaction of the intervention group against dummy variable.

Statistical analysis, including distributions and graphical representations (step 5)) was done in IBM SPSS Statistics version 24 and then imported into Microsoft Word. Graphical representations were chosen depending on the type of statistical analysis and the information to be represented. For instance, I used Kaplain-Meier survival curves for survival analysis. The interpretation of the data involved not only making sense of the numbers, tabulations, graphics and individual quotes, but also being imaginative and
analytical enough to see the relationship between the different forms of information representation as a whole. This process of data interpretation allowed me to find relationships, explanations, and understandings of what the data was saying. In addition, it served as a validation exercise, helping me to explain the data and also to check for data consistency and quality. When explaining the data, I used the quotes of respondents to illustrate and emphasise certain viewpoints. The explanations were backed up by tables and/or graphics to provide visual clarity and comparisons.

5.3 Ethical considerations

In this research, a number of ethical considerations were taken into account throughout the studies. We followed the Swedish and Mozambican rules and guidelines for research involving humans. Ethical approval to conduct the research in Mozambique was granted by the National Bioethics Committee for Health (CNBS) of the Ministry of Health in Mozambique (IRB#: 00002657) and the Institutional Bioethics Committee on Health, at the Faculty of Medicine of Maputo Central Hospital (PR# CIBS FM&HCM/78/2014). In Sweden, the ethical vetting was approved by the Regional Ethical Review Board at Uppsala (Dnr 2105/082). The following paragraphs explain the rules and guidelines followed.

Participating in the study was voluntary and there was no obligation to participate. Participants were able to withdraw from the study at any time without providing a reason or having any negative consequences. Participants were clearly and adequately informed about the purposes of the study and its likely benefits. Confidentiality was maintained through the coding of participants and the removal of identifiers at an early stage in the data analysis. The consent to participate in the study (Paper 4) involved giving written consent (for healthcare workers) and oral consent (for patients). The questionnaires to both groups (healthcare workers and patients) were accompanied by a participant information statement. The participant information statement outlined the purposes of the study, the methods of the research, a timeline, the name of the researchers and the name of contact people for further information. The information statement also included a statement about any possible risks and/or discomfort that might arise for the participant and the subsequent actions and responsibilities of the researchers. The steps required to become involved were clearly articulated along with a statement noting that withdrawal from the study could occur at any time without any negative consequences for the participant.
Information about the participants was kept in secure storage both whilst the study was being conducted and after the study was completed. The information is stored in paper copies, tape recordings, computer files and on compact disc. The data are only accessible to the research team. The storage locations are on secured computers in the offices of the research team. The hard copy data are stored in a locked cupboard in the office of José Nhavoto at Eduardo Mondlane University in Mozambique. Identifiers were used only to ascertain the randomisation of the questionnaire sample and were removed as soon as practicable after the data was coded by computer.
6. The SMSaúde System

The objective of the SMSaúde system, as an information system solution, was to design, develop and implement a communication system for patients having treatment for HIV/AIDS and TB. The solution aimed to improve communication between patients and healthcare workers and to improve retention in care. The SMSaúde system automatically sent text messages to patients, and patients could text back. Data that includes mobile phone numbers, dates of the patient’s next appointment, and dates of their next collection of medication were extracted from local databases and sent to a centralised database.

This chapter describes the design, development, and implementation process of SMSaúde. The design section (section 6.1) describes the technical characteristics, requirements, and system features. The development section (section 6.2) describes the process of development of SMSaúde. Section 6.3 discusses the process of implementation and sections 6.4 and 6.5 discuss information flows and the impact of SMSaúde on information flow.

6.1 System design

6.1.1 Technical characteristics
The system design of the SMSaúde is presented below (Figure 6.1)
The SMSaúde system has two layers:

1) **Server:** on the server side, there are five elements:

   a. Server databases which comprise health records (*health records database* [DB]) and a text message server (SMS server). The *health records DB* contains data originated from the client PC and the SMS server contains text messages (scheduled, outgoing and incoming). All databases are MySQL server-based.

   b. A web service containing services that allow the server to communicate with the client PC. The web service allows the server to authenticate the client PC and receive data from the DataSync App.

   c. An SMStrigger app that processes the data stored in the *health records DB* to create SMS text messages. SMS text messages are created and stored in the SMS server database.

   d. The SMSaúde Portal, which allows users to access patient data and text messages.

   e. A Global System for Mobile Communications (GSM) modem used to communicate between the SMS server and patients (it sends and receives SMS text messages).

2) **Client:** on the client side, there are four main elements:

   a. The local database of the EPTS. This database contains patient records.

   b. The Datasync database (*DataSync DB*) that contains records of patients registered as part of the SMSaúde project.

   c. The DataSync App, the application that fetches and sends patient data to the data server (*health records DB*).

   d. A GSM modem used to connect to the internet and communicate with the server.

### 6.1.2 Requirements

The following are the technical requirements of the system:

1) *.Net Framework 3.5 or higher* – this is the platform used to develop all applications like DataSync and SMStrigger. Usually, this framework is installed along with some applications like MS Office.

2) *Database server* – this is the MySQL server used to store data. These data are about patient records and text messages.
3) *Sistema Hdd_be* and *sespth* – these are the local databases containing patient data. They are part of the EPTS. The first database contains the records for patients on ART and the second contains the health records of patients on TB treatment. *Sistema Hdd_be* is based on Microsoft Access and *sespth* is based on the MySQL server.

4) *GSM modem/SMPP (Short Message Peer to Peer)* – the modem is required for client PCs to connect to the internet and to be able to communicate with the server, and on the server side, the SMPP protocol is required to send and receive text messages.

5) *Internet Information Services (IIS)* – The IIS is required to run the web service on the server. IIS is used to make the services like *receivePatientData*, *receiveAppointmentData*, and *receiveMedicationData* available to the DataSync App. In addition, IIS makes DataSync App available to the external world.

The following are the human resources required to operate the system:

1) Data entry clerk – this person enters regularly data into the EPTS system.

2) Administrator – this person manages the administration of the system. He constantly monitors and manages the system. His role is also to observe how the system operates in terms of its performance, check if data is being received, and check whether messages are sent to patients.

6.1.3 System features

The features of the SMSaúde system include:

1) *Automatic data capture* – captures patient data including schedules for the next appointments and next date of collection of medication.

2) *Automatic data management* – automatically sends data captured from the health centre computers to the central server. As the GSM networks in Mozambique are often unreliable, especially in rural areas, we designed a mechanism of storing data locally and sending it to the main server whenever a connection is established. This way we can get daily updates in most cases, although not necessarily at a predefined time every day.
3) **Data checks** – the DataSync App and SMSaúde Portal feature ways to check data accuracy. Mobile phone numbers, dates of next collection of medication, and dates of the next appointment were frequently checked.

4) **System scalability** – scalability here means that the system was able to accept the addition of new health centres and more patients. The addition of a health centre did not disrupt the normal function of the system. The system was developed with this in mind as there was a need for expansion in the coverage of health centres.

5) **Two-way communication** – the system was designed to send and receive text messages from patients. The system could also allow authenticated users like the administrator to reply to text messages.

6) **Auto-reply text messages** – this feature was designed to allow the system to automatically respond to text messages sent by patients. The feature scanned each incoming SMS for a match with a configured regular expression and replied to them automatically.

### 6.2 System development

The development of the system was done using pre-selected tools. The general idea was that the system should be developed as an open source solution, therefore, open source software was used to build the main components. Proprietary software, like Microsoft Visual Studio, was used to design the interfaces and services. However, the source code was maintained open for free distribution.

During the process of the development of the solution, there were various iterations between the management team of ARK and myself. Primarily the objective of the iterations was to study the context of the solution to be developed. The process of the development of different components required negotiations with ARK’s staff with the aim of seamlessly integrating the main components of the SMSaúde system with the existing HIS. Various meetings were set up in order to understand the multiplicity of factors, structures, interests, tasks and the existing EPTS. The differences between the EPTS for HIV/AIDS and EPTS for TB were analysed aiming to explore the rationales behind these systems (e.g. database systems, data types), and how they have been designed (e.g. system architecture). The analysis of these various rationales, which underpin the local work practices of data collection and the organisation’s practices in different implementation sites, was important in order to understand the challenges of the integration of SMSaúde with the two EPTS systems.
The understanding of these challenges proceeded with the development of different components of the systems, which consisted of various phases. The main phases were the development of:

1) databases for client and server apps;
2) the DataSync app;
3) services for the integration of DataSync with the EPTS;
4) a web service for data exchange between DataSync and the server;
5) SMStrigger for generating the SMS;
6) services for sending and receiving SMS, and
7) interfaces for data visualisation. The main two interfaces are shown in Figures 6.2 and 6.3. Figure 6.2 shows an example of the interface of the DataSync App for HIV.

![Image of DataSync App interface](image)

**Figure 6.2. DataSync App interface**

The interface shows that the DataSync App has two main parts: the main menu and the button to send data to the server (*Enviar os Dados para o servidor*). The main menu is composed of the following elements:

1) Exit (*Sair*) – this allows users to exit the app and minimise it in the taskbar.
2) Patients (*Pacientes*) – this allows the user to view all the patients recruited for SMSaúde. This menu item has three elements: 1)
list of patients on pre-ARV (Pre-TARV), 2) a list of patients on ART (TARV), and 3) a list of patients with errors in their mobile phone numbers (Pacientes com erros no contacto).

3) Medication (Levantamentos) – this allows the user to view information about the future dates of collection of medication. This menu item has two elements: 1) a list of patients with the future dates for the collection of medication (Lista de futuros levantamentos), and 2) a list of the future dates of collection for medication, with errors (Lista de levantamentos com erros).

4) Appointments (Seguimentos) – this allows the user to view information about the future dates of appointments. This menu item has three elements: 1) a list of appointments for patients on pre-ART (Lista de seguimentos de pacientes em Pre-TARV), 2) a list of appointments for patients on ARV (Lista de seguimentos de pacientes em TARV), and 3) a list of appointments with errors on the dates (Lista de seguimentos com erros).

Figure 6.3 shows the interface of the SMSaúde Portal. The interface enables authenticated users to visualise the patient data captured at different healthcare centres, and the text messages (sent and received).
The interface of the SMSaúde Portal is composed of a menu with four elements:

1) Patients (PACIENTES) – this area shows information about the patients registered to receive text messages. This menu item has three elements: 1) a list of patients on pre-ART (Pre-TARV), 2) a list of patients on ART (TARV), and 3) a list of patients with errors in their mobile phone numbers (Pacientes com erros no contacto).

2) Medication (LEVANTAMENTOS) – this area shows information on the patients with dates of collection of medication. This menu item has two elements: 1) a list of patients with the dates of their next collection of medication (Lista de levantamentos), and 2) a list of patients with errors on their dates of collection of medication (Lista de levantamentos com erros).

3) Appointments (SEGUIEMNTOS) – this area shows information on the patients with the dates of their next appointments. This menu item has three elements: 1) a list of appointments for patients on pre-ART (Lista de seguimentos de pacientes em Pre-TARV), 2) a list of appointments for patients on ARV (Lista de seguimentos de pacientes em TARV), and 3) a list of appointments with errors on the dates (Lista de seguimentos com erros).

4) Text messages (MENSAGENS) – this area shows all text messages. This menu item has three elements: 1) scheduled text messages (Mensagens Agendadas), 2) outgoing text messages (Mensagens Enviadas), and 3) oncoming text messages (Mensagens Recebidas).

There have been various updates of the system. The updates consisted of improvements aiming to optimise the system. For instance, new versions of DataSync emerged as new requirements for data and features were defined. Most updates involved optimising the algorithms for the different components of the system. For instance, as more patients were recruited into the system, updates were done for the algorithms that sent and received data. At the same time, the algorithms that processed the data to generate SMS were updated. I mainly took charge of the operationalisation of the changes and the data manager mainly worked on the implementation of the new version in the implementation sites.
6.3 System implementation

The implementation of SMaúde was done in five healthcare centres in Maputo. These healthcare centres were Namaacha, Matola II and Machava II for HIV and Machava II, Matola I, Matola II and Ndlavela for TB. All of the sites were selected by ARK as places where they already had medical interventions set up.

The process of implementation in the sites first required setting up the environment, and this involved checking for the technical requirements presented in subsection 6.1.2. The next step involved the installation of DataSync. Installation was done remotely after the remove connection environment had been set up and configured. During the installation process, there were configurations for databases and other components, including the GSM modem.

The application DataSync is available for installation from the following link: http://197.249.4.227:4404/smsaudetarv/default.html. Figure 6.4 shows the image of the result after running the link aforementioned. The app can be downloaded by clicking Install.

![Installation link for DataSync app](image_url)

*Figure 6.4. Installation link for DataSync app*
The installation of the app is straightforward. After the installation, we proceeded with testing the solution and this consisted of making sure that the installation had been done successfully and that DataSync was connected to the remote server. Testing also consisted of sending data to the server and making sure that DataSync collected and sent the right data.

Other than meeting the technical requirements, one of the requirements of DataSync was that that healthcare workers (e.g., physicians, data entry clerks, and pharmacists) had to be involved. Only the data entry clerks were directly involved with DataSync, as they entered the data in the EPTS and had access to DataSync, but the other healthcare workers contributed by providing data. They were encouraged to do so in a timely fashion.

The maintenance of DataSync involved not only myself, as the designer and developer of the system, but also the data manager and data entry clerks who were part of ARK. My role during the implementation was 1) to ensure that the installations and connections between DataSync and the server were done correctly, 2) to ensure that DataSync was collecting and sending the right data to the server, and 3) to perform changes to improve the versions of the system. The data manager role was 1) to ensure that data was entered regularly in the EPTS and 2) to bridge the communication gap between the data entry clerks and those providing the data (e.g., physicians and pharmacists). The data entry clerk had the role of 1) entering data in the EPTS, 2) making sure that the GSM modem was connected to the network, and 3) checking DataSync for the data that needed to be corrected. Through the interface of DataSync, it was the role of the data entry clerks to visualise the data that was entered incorrectly. It was only possible to see data for the patients of the SMSaúde programme.

On the server side, my roles were to install all the components of the system and to make sure that the necessary connections worked well. In addition, I made sure that the SMS were created based on rules set by ARK and that the SMS were sent to patients. Furthermore, I assisted in performing updates of the system components. The role of the data manager was to make sure that data was received by the server, and that the SMS were sent to patients. In general, the data manager and I maintained the system.

6.4 Information flow

The SMSaúde system requires that information flows regularly from different healthcare workers until it reaches the system. From the health centre level to the server level, the information flow is represented in Figure 6.5.
Physicians and pharmacists regularly fill in forms. The forms filled in by the physicians contain patient information which includes background, phone number, characteristics specific to a particular treatment, and dates of the last and next appointments. The forms filled in by the pharmacists contain information that includes the dates of the last and next collection of medication. Physicians and pharmacists are required to deliver the forms to the data entry clerk who enters the data into the EPTS system. The DataSync app fetches the data from the EPTS for patients that have been registered as part of SMSaúde. Patient mobile phone numbers in the EPTS were marked with an NP and NC if they were to receive text messages or not. Data captured by the DataSync app are sent to the data server. Data received from the DataSync app are processed, and SMS text messages are sent to patients by the SMS server. Patients can interact with the SMS server.

6.5 The impact of SMSaúde on information flow

Prior to the introduction of SMSaúde, information flows suffered from a number of problems. There were problems with delays from the physician and pharmacist-side, in terms of delivering the forms to the data entry clerk
quickly. Physicians and pharmacists delivered forms to the data entry clerk at the speed of one week after they had filled them in, or even a few days before the date of the next appointment or collection of medication. Then, the data entry clerks delayed entering the data into the EPTS. It used to be common to find a pile of forms in the data entry clerk’s office.

Data accuracy was another issue. Physicians and pharmacists did a lot of work, but reported less. During the day they worked hard and in the afternoon they tried to remember what they had done throughout the day for information purposes. The shortage of personnel was one of the issues that influenced this problem, because in many cases a single person was involved in many activities. Filling in forms was considered to be less important than completing all of the other activities. Thus, the information completed in the forms was what the worker remembered that they had done during the day. This issue of data accuracy was also influenced by the lack of a culture in terms of the proper completion of data. Physicians and pharmacists knew that they had to complete forms, but they did not understand how important it was to do the work frequently and accurately. They understood that the data was important for reporting to higher levels, but not that it could be used locally. The forms were mechanically completed, without understanding their purpose. Another issue was information checks. For example, the next appointments were generally scheduled for the next month. There were situations where the date was not calculated correctly. The non-use of data collected for decision-making and feedback was one of the issues that made physicians and pharmacists unconcerned about the truthfulness of the data in the forms they completed.

The SMSaúde project contributed to many changes at the health centre level. Firstly, realising that there was a shortage of personnel, the project closed a deal with the MoH that included hiring more physicians, pharmacists, and data entry clerks. It is important to note that data entry clerks as a category do not exist within the organisational structure of the MoH. The MoH only recognises data specialists as a category. Data entry clerks were introduced by non-government organisations when they introduced computer-based systems like the EPTS.

Secondly, the speed of information flow was changed. Physicians and pharmacists were motivated to complete forms every time they met a patient. Completed forms were sent every day to the data entry clerk in the afternoon. Physicians and pharmacist had to deliver the forms personally, but the data entry clerks could also collect the forms in cases of delays. The
data entry clerks had to enter data every day. The forms collected in the afternoon were entered in the EPTS usually by the next day, in the morning.

Lastly, the DataSync app and SMSaúde Portal allowed data entry clerks and registered users to check for data accuracy. The DataSync app allowed the data entry clerk to check the mobile phone contacts, dates of next appointments and dates of next collection of medication for accuracy. For instance, mobile phone contacts shorter than 9 digits (in Mozambique the length of a mobile phone number, excluding the country code digits, is 9) were highlighted to the data entry clerk in the system. The data entry clerk could then print the list of patients with incorrect mobile phone numbers and present it to physicians, who could contact the patients and correct the numbers. Commonly, physicians corrected this information the next time they met with the patient. As the next meeting usually happened a month later, physicians put a sticker in the patient folder to mark that they needed to correct some information.

The DataSync app also displayed the patients with errors in terms of the dates of their next appointment or the date of their next collection of medication. Checks for dates were done based on rules depending on the type of treatment. For example, patients on ART should collect their medication monthly. If the difference between the date of the last pick-up and the next refill was larger than 32 days (the dates of next collection are calculated by a pharmacist and a date can only fall on a weekday, so if, for instance, the date after 30 days coincided with a Sunday, one more day had to be added) then the date of the next appointment was considered incorrect. Patients who had not yet initiated ART could have their appointments booked every three months. In these cases, if the date of the next appointment was later than three months ahead, then it was signalled as an incorrect date.
7. Summary of the Papers

This chapter summarises the empirical findings of Papers I-V. Table 7.1 summarises the principal findings of the papers and links them to the research questions.

<table>
<thead>
<tr>
<th>Papers</th>
<th>Research Questions</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mobile Technologies and Geographic Information Systems to Improve Health Care Systems: A Literature Review</td>
<td>1) What is the geographical distribution of the publications on mobile technologies and GIS? 2) How have mobile technologies and GIS been used to improve health care? 3) What were the effects associated with the use of mobile technologies and GIS?</td>
<td>Most applications of mobile technologies and GIS are in developed countries including the USA, the UK and Canada. Mobile technology apps can be categorised in six themes and, for GIS, in four themes. They are used to address a variety of health conditions including chronic disease, HIV/AIDS, and TB. Overall, their effects on healthcare are positive.</td>
</tr>
<tr>
<td>2. SMSaúde: Design, Development, and Implementation of a Remote/Mobile Patient Management System to Improve Retention in Care for HIV/AIDS and Tuberculosis Patients</td>
<td>How can we design, develop and implement an integrated mobile phone text messaging system that could be used for HIV/AIDS and TB?</td>
<td>There are six sets of system requirements for the design and implementation of a successful integrated text messaging system. The requirements need to be handled with care in order to make sure that the information systems system is successful and useful to support health healthcare services.</td>
</tr>
<tr>
<td>3. SMSaúde: Evaluating Mobile Phone Text Reminders to Improve Retention in HIV Care for Patients on Antiretroviral Therapy in Mozambique</td>
<td>What are the effects of the use of a mobile phone-based system on retention in treatment?</td>
<td>Patients who received text messages had lower attrition rates at 12 months. SMS text messages significantly improved the retention rates in the HIV care of urban patients, and of those who recently initiated care, compared to standard care.</td>
</tr>
<tr>
<td>4. Mobile Health Treatment Support</td>
<td>1) What are the attitudes among patients and healthcare workers</td>
<td>The majority of both HCW and patients found the SMSaúde system</td>
</tr>
<tr>
<td>5. Use of Mobile Technologies to Improve Health Care in Mozambique: Key Failure/Success Factors, Challenges, and Policy Implications</td>
<td></td>
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<tr>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) What is the current state of mHealth implementation in Mozambique?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) What are the challenges, success and failure factors of mHealth projects in Mozambique?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mHealth applications in Mozambique were classified in six categories. Apps centre on the use of SMS and data on basic phones, feature phones, smartphones and tables. Insufficient funding, lack of technical expertise, and regulatory issues are the key failure factors. For projects that scaled-up, there are success factors. Thirteen challenges were found, including HCW workload, technological issues (e.g. unreliable internet connection and poor reception), privacy and safety concerns, lack of ICT skills, and the lack of a proper legal framework and poor regulation.</td>
<td></td>
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</tbody>
</table>

### 7.1 Paper I

**Title:** Mobile Technologies and Geographic Information Systems to Improve Health Care Systems: A Literature Review.

This paper contributes to the body of knowledge on mobile technology and GIS use to improve healthcare systems. It answers the first research question posed in this thesis: “What is the potential of using mobile technologies to improve healthcare?”

The study provides a systematic review of mobile technologies and GIS research within the specific area of healthcare, during the period 2005-
2012. We investigated 1) the geographical distribution of publications on mobile technologies and GIS, 2) how the mobile technologies and GIS improve healthcare and 3) the effects of the use of these technologies.

The findings reveal that most interventions concern developed countries, with countries like the USA, the UK, and Canada leading the others. Applications of mobile technologies can be categorised into six themes: treatment and disease management, data collection and disease surveillance, health support systems, health promotion and disease prevention, communication between patients and health care providers or among providers, and medical education. GIS applications can be categorised by four themes: disease surveillance, health support systems, health promotion and disease prevention, and communication to or between health care providers.

The dominant research focus is on the use of text messaging for communication between patients and health care providers, mainly for reminders and advice to patients. Although most mobile phone-based interventions have a limited number of participants, in general, they have modest benefits and may be appropriate for implementation. GIS technology also exhibits modest benefits, such as an improved understanding of the interplay of psychological, social, environmental, and socio-demographic influences on physical activity.

7.2 Paper II
Title: SMSaúde: Design, Development, and Implementation of a Remote/Mobile Patient Management System to Improve Retention in Care for HIV/AIDS and Tuberculosis Patients.

This paper presents and discusses the requirements for the design and development of the text messaging system called SMSaúde. The SMSaúde system was integrated with a routine health information system for two healthcare programmes: HIV/AIDS and TB. The integrated system was used to follow-up with patients in three HIV and four TB public healthcare centres in Maputo, Mozambique. The paper answers the second research questions of this thesis: “What are the technical requirements to design, develop and implement an integrated mobile phone text messaging system for HIV/AIDS and TB?”

The general design guidelines in the literature were found insufficient to address the functionality adaptation of such types of information system intended for users with different needs. In this research, we focused on the first four steps of DSR methodology to develop and implement a web-based
system. The research activity to design, develop and implement the SMSaúde system involved healthcare professionals, technical experts and an interdisciplinary group of researchers. These actors were imported to enhance the utility and functionality of the system.

Findings show that there were seven sets of system requirements that needed to be addressed for successful design: the functionalities of the system, data collection, telecommunication costs, privacy and data security, text message content, connectivity, and system scalability. These requirements are somewhat locally important, i.e. are context situated and therefore can be addressed differently and they come with different urgency levels. Nonetheless, the implementation of the system requires that these requirements be addressed in order to successfully implement a working system in low-resource settings like Mozambique.

7.3 Paper III
Title: SMSaúde: Evaluating Mobile Phone Text Reminders to Improve Retention in HIV Care for Patients on Antiretroviral Therapy in Mozambique.

This paper is based on empirical data about HIV/AIDS patients and retention. The integrated SMSaúde system, presented in paper 2, was evaluated for its effectiveness. We evaluated whether regular mobile phone text reminders improved the retention of patients in HIV/AIDS care in three healthcare centres in Maputo, Mozambique. The aim was to answer the third research question: “What are the effects of the use of a mobile phone-based system on retention in treatment for HIV patients?”

The article has three findings. First, overall, SMS reminders did not significantly improve retention in HIV/AIDS care at 12 months. The retention rate of patients in the intervention group was slightly higher than those in the control group (94% vs. 91%). In addition, SMS reminders did not improve patient attrition incidence per 100 person-years in HIV/AIDS care. The attrition incidence was higher in the control group than in the intervention group (9.5 vs. 6.4).

Second, post-hoc analysis revealed that SMS reminders improved retention among patients in the urban area; retention was significantly higher in the intervention group than in the control group (94% vs. 90%, p=0.032). Among patients in the rural area, SMS reminders did not significantly improve retention, and in fact those in the control group had a higher retention
rate than those in the intervention group (97% vs. 91%). The SMS reminders also improved the attrition incidence among urban patients. Patients in the intervention group had a lower attrition incidence than those in the control group (5.8 vs. 10.7). Among rural patients, the SMS reminders did not improve attrition incidence. Patients in the control group had a lower attrition incidence than those in the intervention group (3.1 vs. 15.3).

Third, among patients who recently initiated HIV/AIDS care (≤3 months), the risk of attrition for those who received SMS reminders was one-third of that in the control group (.33 vs. .91); the same was true for non-urban patients (.34 vs. .96) and urban patients (.20 vs. .64). The findings suggest a retention improvement for patients in HIV/AIDS care. As discussed in the paper and also in Paper IV, a possible explanation for the low effects of the intervention is that the project in itself may have affected the retention in treatment, so the control group also had unusually good retention rates.

7.4 Paper IV

Title: Mobile Health Treatment Support Intervention for HIV and Tuberculosis in Mozambique: Perspectives of Patients and Healthcare Workers.

This paper is based on empirical data on two groups of users of the SMSaúde system: healthcare workers and HIV and TB patients. The research question is “What are the user perspectives on the integrated mobile phone-based system for HIV and TB treatment?” We studied users’ perspectives on the SMSaúde system and investigated patients’ attitudes in relation to their demographics.

The findings reveal that, first, both patients and HCW found the SMS system useful and reliable. They perceived the system to be useful in reducing failures to collect medication and avoiding missed hospital appointments. In addition, they would recommend the system to other patients and/or healthcare centres. Second, the SMSaúde users felt confident with the system, although they mentioned the risks of unintentional disclosure of health status. Lastly, the automatic reply feature was appreciated by patients. This unique feature of the system allowed patients to get automatic answers to their questions. These findings suggest that a system like SMSaúde should be used to transmit SMS reminders aiming to improve retention in care for diseases like HIV/AIDS and TB.
7.5 Paper V

Title: Use of Mobile Technologies to Improve Health Care in Mozambique: Key Failure/Success Factors, Challenges, and Policy Implications.

This paper draws from empirical data on the use of mobile technologies in Mozambique. The paper extends the work done in paper 1, in that it investigates the uses of mobile technology in a very specific context. In this paper, we aimed to answer the following research question: “What are the applications, challenges, success/failure factors and implications for the policy of mHealth interventions in Mozambique?”

The findings reveal that the mHealth applications of mobile technologies include client education and behaviour change communication, data collection and reporting, electronic decision support, provider-to-provider communication, provider training and education, supply chain management, and financial transactions and incentives. The applications use mainly the SMS and data features of the phone. The devices used by providers include basic phones, feature phones, smartphones and tablet phones, while the design of the services targeted mainly patients using basic phones, and the target actors were healthcare workers.

Additionally, the article highlights challenges for the implementation of mobile technologies in the context of a resource-constrained country. Failure factors for mHealth projects that were not successfully implemented and success factors for mHealth projects that were scaled up are presented. Furthermore, the article discusses an approach to drive the development of an mHealth policy and strategy in Mozambique.
8. Conclusions and Final Remarks

This chapter summarises and discusses the findings of this thesis. It also discusses the theoretical and practical contributions of the thesis to the field of information systems in healthcare.

8.1 Summary and discussions

This research has explored the research question: How can mobile technology be effectively integrated with routine health care services? The thesis project developed and evaluated new technology and new work methods for a number of health care centres in Mozambique, but beyond the direct achievements, the thesis has also addressed the larger issue of the integration of mobile technologies with routine healthcare services for HIV/AIDS and TB, which is necessary in order to be able to scale up systems. The discussion focuses on the crucial issue of integration, the benefits of use of the design-based methodology, and the scaling up of the integrated IS artefact, all in relation to the research papers summarised in the previous chapter.

8.1.1 Integration of HIS

In this thesis, the integration of HIS is based on the broader perspective of information systems integration – that of the people, organisational routines and technical aspects involved. The integration project is built from two cases of routine healthcare services for HIV/AIDS and TB. These are examined to identify the requirements and challenges associated with the process of integrating the individual information systems with mobile phone-based services. The analyses regarding the integration of mobile phone-based systems with routine HIV/AIDS and TB services, from the design, development and implementation perspectives, are thoroughly described in Paper 2.

The empirical findings in Paper 2 and Paper 5 show that the institutional contexts of HIS are important for integration. The institutional context is the long-established management information system, which reflects the current service health provision system. The existing HIS had various issues related to fragmented information systems that needed to be addressed. Issues included, for instance, the duplication of data collection efforts, an unoptimised information flow and the lack of a unified communication system between healthcare workers and patients. The SMSaúde system emerged under the promise that the system would solve the problem of integration. In addition, the integration meant that some changes to the existing HIS (e.g., related to information flow) could be beneficial to both the NGO and
the health practitioners at the healthcare centre level. This implied that the integration would allow shared, effective, and efficient interventions. The latter is important in an environment where both the MoH and NGOs struggle to effectively manage the scarce resources they have available to improve the well-being of the population.

The processes in the new integrated HIS i.e. the old HIS integrated with the SMSaúde system, are different from those of the old, fragmented HIS. The new integrated HIS brought benefits beyond those related to an integrated communication system. The benefits of the new integrated HIS include an improvement in organisation-wide performance, efficiency in communication (sending and receiving text messages), efficiency in data collection, improved data quality, and sharing of information.

The process of integrating information systems artefacts with routine healthcare services requires collaboration between various health actors, as found in Paper 5. This means, on the one hand, that healthcare professionals, including medical personnel, data specialists and systems administrators, must work together to help achieve the goals of providing better healthcare services to the population. On the other hand, NGOs, donors and the MoH need to work collaboratively in order to ensure that the integrated information systems artefact gets its place within the organisational context. Hence, these actors need to form an alliance in which the creation and adoption of the new integrated HIS is accepted by all. The discussion here does not aim at forcing alliances for the new integrated HIS; rather, at examining the roles of each actor for the new integrated HIS to be successful and useful. Undoubtedly, the new integrated HIS is a better way of achieving effective healthcare provision. However, the achievability of integration is an interesting discussion, because without these actors – donors, healthcare professionals, and the MoH – the integration would not have taken place. Healthcare professionals are the ones that produce the data and ensure health provision, and donors use the data to justify their presence and apply for support from their financiers. The MoH ensures that the existing policies are translated in a way that the donors and healthcare workers understand them along the way of implementing the integrated systems.

Besides the challenges described in Paper 5 (e.g., the scarcity of skilled personnel, the lack of financial resources), the integration of HIS faces pressure from internal and external forces which originate from the power of various stakeholders. This power is exercised in the day-to-day routines of those who are directly related to the HIS. Such power has an effect on the information system and, therefore, system designers need to be careful when
addressing the issue of integration. A careful reflection on what to integrate, when, where and with whom, is necessary in order to seamlessly achieve the goals of an integrated HIS.

### 8.1.2 Benefits of DSR

The use of DSR provided a theoretical underpinning to design, develop, test and implement the SMShude system, a system which addresses the problem of the lack of integration of the HIS in Mozambique. The SMShude system, which is an information system artefact, addresses the problem in the context of HIV/AIDS and TB services. This was possible through following the seven guidelines presented by Hevner et al. (2004). The guidelines acted as a catalyst for the subsequent steps, which overall were the basis for generating new knowledge on, and understanding of, the problem. The first step of the design process, which illuminates the purpose of DSR, consisted of identifying the research problem (Paper 1). The findings from Paper 1 contributed to the idea of having an information system artefact that could help address health problems and improve health services in Maputo.

The contextualisation of problems in an organisational setting is important so as to avoid designing solutions that do not solve context-based problems. For this, user involvement is crucial. To appropriately contextualise the problem, meetings with key people from ARK were held in order to understand the organisation, to define the specific research problem and to justify the value of the solution. The knowledge gained from discussions in meetings was used to define the objectives of the solution. Through various interactions, it was possible to define the scope of what was possible and feasible, and the objectives were then aligned to the core objectives of the organisation. In this way, it was possible to define objectives for a solution that could address the main issue of integration.

During the design and development phase, the artefact’s desired functionalities and its architecture were determined. As described in Paper 2, these functionalities included developing an artefact that automatically could send SMS to patients using two-way communication. While not completely unique, two-way communication it is unusual in systems like the SMShude, and users (both patients and healthcare workers) liked it (Paper 3). In particular, the survey shows that patients got the sense that the healthcare workers cared about their health.

One core feature of DSR is iteration. Multiple iterations allowed us to test the current artefact and inputs were used to improve the artefact until a final version was produced. The initial demonstration of the SMShude
artefact was first done in four healthcare centres in Maputo. As DSR requires observation and measurement of how well the artefact addresses the problem, evaluations during the integration of the artefact, as well post-artefact integration, were carried out. During integration, in Paper 2, the evaluation of the information system artefact was done in order to test the artefact against seven quality criteria. The quality criteria – functionality, completeness, consistency, accuracy, performance, reliability, and usability – were important measures to make sure that the information system artefact was fit for the needs of patients and healthcare providers. Evaluation post-artefact integration, in terms of the usefulness of the information system artefact – a basic requirement in DSR – was done in Paper 3. The evaluation continued in Paper 4, where an investigation of the effects on patient outcomes was launched.

The design of a system like SMSaúde includes special attention to not only the theoretical foundations, but also the requirements for optimal development, including how various parts of the system can be connected to make up the whole system. Requirements include those related to data (e.g. clean data and security), connectivity (which is basically required for communication between the remote EPTS and the server), trust, usefulness, usability and system scalability. Other crucial issues for the system include how to deal with important features such as tailored SMS content, how bi-directional communication is optimised to the participants’ situations, and context and privacy standards. Careful attention also needs to be paid to the automatic responses, so as to avoid misinterpreting participants’ text messages and confusing the feedback.

Despite the fact that the system was designed specifically for HIV/AIDS and TB, the advantage of the strategy is that it caters well for local needs (e.g. cultural and social aspects), which may be particularly important in resource-constrained settings.

### 8.1.3 Scaling up

The scaling up of information system artefacts is a crucial issue in many projects. The current evidence in Mozambique shows that few mHealth systems go beyond the pilot phase. While some were designed specifically to serve specific purposes, such as proof of concept, some projects don’t scale up due to various reasons. For mHealth systems to go beyond the pilot phase there are many challenges and requirements that need to be addressed. The challenges are of various order, including technological, financial, and human resources.
Designing and developing an mHealth system with scalability requirements, which was the case in the SMSaúde system, is a fundamental principle. This requirement includes mechanisms to facilitate the addition of new electronic patient tracking systems (EPTS) without the need to modify the core of the system. Despite the system’s capabilities, some crucial issues need to be addressed in order to ensure that additions of new EPTS (which means more data and consequently, increased processing demands), do not disrupt the artefact. The crucial issue is how to address the scalability of the mHealth artefact. As in the case of the scale-up to Gaza, the system requires investments of various types. First, there is the need to invest in the technical capabilities, which includes hardware and software. On the hardware side, a powerful server is essential to ensure that large amounts of data are processed optimally. On the software side, it is crucial that the information model of the mHealth systems is compatible with the systems already storing patient data that should be integrated with it. Any changes, e.g., of the EPTS, would require modification of the mHealth artefact. As in Mozambique, many HIV/AIDS and TB programmes use different computer-based systems, and this is a challenge.

Second, data collection is important, as the mHealth artefact depends on it to communicate with patients. Two aspects are crucial. One is to ensure that data is entered on time in the EPTS, and the other is to ensure that the data is of good quality. In addition to providing algorithms for data validation, it is important to regularly provide training for healthcare workers (including physicians, nurses and data entry clerks) on the issues of data entry and data quality, as we did in our project. This should be done as an integrated part of a national strategy by the MoH.

Third, cost-effective measures are important to optimise the cost of communication which includes the costs for the SMS, data communication between the server and the remote computer hosting the EPTS, and the salaries for data entry clerks. Even though some mHealth projects, like the SMSaúde one, have partnered with a telecom operator to pay for the costs of SMS and data communication, this is not a sustainable solution and alternative financing must be established. Salaries for data entry clerks are also an issue, since these people are not yet recognized as part of the Mozambican healthcare personnel body. Most projects pay salaries for people they hire to do these types of work. It is crucial that the MoH, perhaps in collaboration with donor organisations, find sustainable ways of financing the operation of mHealth solutions.
While relying on donors can be effective for initiating mHealth systems and running them in some scale and for some period of time, it is not necessarily conducive for large-scale implementation. For that, standards for both technology and operational procedures are needed, as well as long-term funding.

Certainly, scaling up a system requires not only addressing all the challenges, but also moving slowly, to make sure that all users (including the potential beneficiaries like patients and healthcare professionals) are on board.

8.2 Contributions

This thesis makes three key contributions to the field of information systems for health. First, we present contributions to the theory in relation to the DSR literature on LDCs. Secondly, we present practical contributions related to how the SMSaúde project changed work practices and information flow. Lastly, we present the contribution to mHealth in LDCs.

8.2.1 Contributions to theory

Few formal studies have used DSR in a LDC context. This thesis contributes to the growing body of literature on DSR and helps to illuminate how DSR can be used to design and implement quality artefacts in LDCs. The contribution relates to the understanding of a phenomenon that involves linking different entities for the development of a technological artefact, generating an “understanding that could only be gained from the specific act of construction” (Vaishnavi & Kuechler, 2004).

The thesis examines the appropriateness of the design principles and strategies that have been recommended in the previous literature on DSR. It demonstrates how DSR can be performed, through following a well-established design framework, to develop a high quality artefact in a LDC context. This effort is in line with the Hevner et al. (2004) argument that “Design Science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation”, and also that the developed artefacts must be evaluated through a rigorous process that may involve data analysis and formalisms, among other well-known evaluation techniques (Mayoka, Rwashana, Mbarika, & Isabalija, 2012).

Specifically, the thesis analyses how the design principles (or constructs) proposed by Hevner and colleagues can be applied in order to develop a functional and implementable artefact. These constructs are used in order to show how DSR theory can be applied in HIS design and evaluation. The
main result of this exercise are the key requirements for designing the mHealth artefact, which were identified as data collection, telecommunication costs, privacy and data security, text message content, connectivity, and system scalability.

8.2.2 Contributions to practice in Mozambique

The study shows that introducing an ICT system such as SMSaúde to support the provision of care on HIV/AIDS and TB within urban and rural primary care settings increases the collaboration between different types of health workers in the healthcare setting. As a result of this, it also increases the organisational attention paid to the specific healthcare domain of HIV/AIDS and TB.

The introduction of SMSaúde increased the knowledge of healthcare workers and patients. SMSaúde empowered patients, allowing them to better manage their wellbeing and health. Healthcare workers improved their practices and relations with patients. Furthermore, SMSaúde improved communication between healthcare providers and patients. Moreover, SMSaúde improved data collection and information flow and quality by reducing the risks of errors by the incorporation of validation mechanisms.

The effects of the SMSaúde project include the design, development and implementation of an electronic patient tracking system called EPTS-TB.

The integrated mobile phone-based solution contributed to promoting HIV/AIDS and TB education and raising the awareness of patients in Mozambique. This was achieved through sending educational SMS periodically. For example, for HIV/AIDS, the SMS included information that encouraged HIV testing and counselling for others. The patients using the system, which contributed to improving their self-management of the disease, had a higher retention in care.

An additional effect of the SMSaúde system is that patients would recommend others with the same or similar disease to use their phone to receive SMS reminders and educational and motivational information. This means that such a project would influence patients to use their phone not only for private matters but also for matters that involved the management of their disease.

The successful adoption and implementation of SMSaúde in Maputo for HIV/AIDS and TB led to the scale-up of the project in the Gaza province. The implementation in Gaza covered 16 healthcare centres and five mobile healthcare centres. This implementation is ongoing as this thesis was being written (in April 2017). This is a great achievement as it augments the reach
of mobile phone-based services and also increases the number of beneficiaries. In Gaza, at least 32,000 patients are benefiting from the service. Such implementations also improve the healthcare system in other ways, including improving information flow and data quality.

Information systems integration is largely described as a socio-technical process, requiring the rationales of the existing health system and the heterogeneity that characterises the information systems to be taken into account (Baxter & Sommerville, 2011). The social aspect, emphasised through the focus on work practices and relations between the different health actors, and the technical systems aspects, emphasised through the technical solutions with their features, all contribute to the historically-situated heterogeneity (Sawyer, 2013). Having in mind that the ultimate goal of any health information system is to allow timely and effective evidence-based decisions, this thesis attempted to find better mechanisms to strengthen the existing disparate information systems through integrating them, with the aim of contributing to public health goals. While the focus of analysis in this thesis is the organisational level, the implications of improvements to the organisation will be felt by patients as well as society-at-large.

8.2.3 Contribution to mHealth in LDCs

While there has been increased enthusiasm for using mHealth solutions for improving healthcare system and health outcomes in Sub-Saharan Africa, there is a paucity of evidence to guide the design, development and implementation of these systems, and even less evidence on the effectiveness of such strategies (Agarwal et al., 2015). A review by Michael et al. (2010) in LMICs found that studies are generally weak and results focus on the intermediary benefits, and they do not show improved workflow, efficiency, quality of care and health outcomes. This thesis contributes to the evidence by providing an understanding of the implications of mHealth-based applications for work practices and patient outcomes. The benefits of the implemented solution are not only felt by patients but also healthcare workers, and the healthcare system management teams.

The thesis also contributes to the understanding of the effects of mobile technology-based systems (the SMSaúde artefact) on primary health care services in low-resource settings such as urban and rural healthcare centres in Maputo, Mozambique. It provides an understanding of how the designed solution affects health outcomes. Additionally, through this evaluation, the thesis investigated and showed the benefits of the artefact in the provision
of HIV/AIDS and TB services. In this regard, the thesis adds to the body of literature on the effects of ICT in LDCs. In addition, it contributes to the understanding of user perceptions of mHealth interventions in LDCs. Moreover, the thesis contributes to the understanding of the challenges and success/failure factors for mHealth implementation in a developing country. The lessons from this understanding have practical implications for mHealth policy, as elaborated in the last paper.

8.3 Final remarks and future research

The thesis took some important steps in generating an understanding of the nature of the challenges of using mobile technology in a resource-constrained context. The thesis also addresses the mechanisms of building an artefact – in this case, software that sends automatic text messages to patients with the aim of improving communication between healthcare workers and patients – and builds an understanding of its effects on patients’ outcomes. The study finds that mHealth solutions can be effectively integrated with two routine healthcare services, namely HIV/AIDS and TB. Future research that builds on my work in this area would be useful in further establishing ways to integrate mHealth solutions with important routine healthcare services other than HIV/AIDS and TB. This research should articulate the existing social, cultural, informational, and technological artefacts, and how the different existing artefacts should interact in order to improve healthcare systems, as well as looking at the possible mHealth solutions. Given the increasing volume of mHealth investment, particularly in Mozambique, research into the effectiveness – including the costs and cost-effectiveness, in both small and large-scale interventions – is necessary.
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World Health Organization.


Annexes

Annex 1: Questionnaire for Paper 4 (for patients)
Annex 2: Questionnaire for Paper 4 (for healthcare workers)
Annex 3: Questionnaire for Paper 5 (for management personnel)
Annex 4: Questionnaire for Paper 5 (for healthcare workers)
Annex 1: Questionnaire for Paper 4 (for patients)

1. Name of the health centre:
   - Machava II
   - Matola I
   - Matola II
   - Namaacha
   - Ndlavela

2. What is your gender?
   - Man
   - Female

3. What is your age?

4. What is your marital status?
   - Single
   - Married
   - Union of facts
   - Divorced
   - Separated
   - Widower

5. Have children under 10 years under your care?
   - Yes
   - No

6. What is your occupation / profession
   - Unemployed
   - Student
   - Employee
   - Dealer
☐ Other:_____

7. What is your monthly household income in MT?
☐ Less than 2,500 Mt
☐ 2500-5000 Mt
☐ 5000-7500 Mt
☐ Mt 7500 or more
☐ Dependent parents / family

8. What kind of transportation do you use to go to the health centre?
☐ Public transport
☐ Car (own)
☐ Bike
☐ Walk

9. How long it takes for you to go to the health centre?
☐ Less than 5 min
☐ 5-30 min
☐ 30-60 min
☐ 1-2 hours
☐ More than 2 hours

10. How much you spend per month (on average) for transport to go to the health centre?
☐ Less than 200 Mt
☐ 200-500 Mt
☐ 500 or more
☐ I don’t know
Read the following statements and choose/mark one of the options below each statement: strongly disagree/disagree/neither agree nor disagree/agree/strongly agree

11. There are risks with SMS system.
12. If you agreed, indicate some.
13. I feel confident with the SMS system.
14. If not you agreed, why?
15. The SMS system helped me not missing appointments.
16. If you’ve missed appointments, how many times?
   - [ ] 0 - No
   - [ ] 1-5
   - [ ] 6 - 10
   - [ ] 11-15
   - [ ] More than 15
17. If you already missed appointments, what was the main reason?
18. The SMS system helped me to remember to collect medication.
19. If you ever missed to collect medication, how many times?
   - [ ] 0 - No
   - [ ] 1-5
   - [ ] 6 - 10
   - [ ] 11-15
   - [ ] More than 15
20. If you ever missed to collect medication, what was/were the main reason(s)?

21. How would you rate the ease of use of the SMS system?
   - Very difficult
   - Difficult
   - Neither difficult nor easy
   - Easy to use
   - Very easy to use

22. I think there are benefits of SMS in terms of receiving education and motivational messages.

23. The content of the text messages is very easy to read and understand.

24. There is some content that you think is missing in the SMS system?
   - Yes
   - No

25. If answer is yes, please, what content is missing?

26. I am willing to use the SMS system in the future to help me with the same disease or another.

27. I would recommend to other patients using SMS system.

Thank you!
Annex 2: Questionnaire for Paper 4 (for healthcare workers)

1. Position / Role at health facility:
   □ Nurse
   □ Medical doctor
   □ Health care technician
   □ Pharmacist
   □ Health Counsellor
   □ Other: _________

2. What is your gender?
   □ Man
   □ Female

3. What is your age?

*Read the following statements and choose/mark one of the options below each statement: strongly disagree/disagree/neither agree nor disagree/agree/strongly agree*

4. The SMS system can help to reduce the number of patients who miss appointments.

5. The SMS system can help to reduce the number of patients who miss collecting medication.

6. The SMS system helps me to discuss health issues related to the patient.

7. There are risks with SMS system.

8. If you agreed, indicate some.

9. There are benefits of motivational and / or education messages.
10. I feel confident with the SMS system.

11. I would recommend other health centres to use the SMS system.

12. If you agreed, explain why.

13. Any idea to contribute for improvement of the SMS system?

Thank you!
Annex 3: Questionnaire for Paper 5 (for management personnel)

A. Personal information
   1. Role in the project
      □ Project coordinator
      □ Project manager
      □ Project director
      □ Decision maker
      □ Other: ____

   2. Gender:
      □ Male
      □ Female

   3. How many years of experience do you have working in the area of mHealth?

   4. For how long have you been/did you working/worked in the project?

B. About the project/programme/intervention
   5. What is the name of the project?

   6. Provide a description of the project/programme

   7. What are/were the goals of the project?

   8. How have you succeeded in meeting your goals?
      □ Yes
      □ No

   9. If No, explain why.

   10. Project/programme type (pilot, full implementation, etc)
       □ Pilot
☐ Full implementation
☐ Study (e.g. randomised control trial)
☐ Other: ____

11. Was your project/program guided by any legal document?
   ☐ Yes
   ☐ No

12. If Yes, which (e.g. ethical approval)?

13. For how long was the project/programme planned?

14. For how long did the project/programme exist/?

15. Who is funding/funded the project (e.g. donors, government, end users)?

16. Who are/were the partners/stakeholders of the project/programme?

17. What are/were their roles?

18. What was the rationale to employ mHealth?

19. How much was the budget?

20. Which mobile device was used in the project/programme?
   ☐ Mobile phone
   ☐ Tablet
   ☐ PDA
   ☐ Other: ____

21. What type of service is/was offered?
   ☐ Text message (SMS)
   ☐ Voice
☐ Multimedia message service (MMS)
☐ Data
☐ Other: ____

22. In which mode did/does your solution operate (offline, online mode, one-way, two-way)?
☐ Online
☐ Offline
☐ One-way communication
☐ Two-way communication
☐ Other: ______

23. Who are/were the beneficiaries of the project/programme (e.g. patients, healthcare workers)?

24. How many people were recruited/benefited (e.g. number of patients, end-users)?

25. To which level was the project/programme planned to be implemented?
☐ Local (community)
☐ District
☐ Province
☐ National
☐ Other: ________

26. Where was/were the implementation site(s)?

27. Was the program integrated into existing healthcare structures in the implementation sites? How?
☐ Yes
28. If yes, how?
29. Who suggested the project/programme (specify the name)?
   - Patients
   - Healthcare staff
   - Government agency
   - Non-Governmental organization (NGO)
   - Other: ________
30. How/did you identify real needs and demands of target beneficiaries?
31. How did you achieve program uptake by end-users (e.g. promotion, education)?
32. Do/Did you collect data on the effectiveness of the program in improving beneficiaries’ outcomes?
   - Yes
   - No
33. If Yes, what monitoring and evaluation metrics do/did you have for your project/programme?
34. What was the business model (if any) of the programs?

C. Challenges
35. What were the challenges you faced (technical [like skills, infrastructure, software, hardware], political/policy, organizational, social)?
36. How did you overcome the challenges?
D. Success/failure factors

37. Did you have to change/alter the profile of the project/programme when faced with a failure?
   □ Yes
   □ No

38. If Yes, what motivated the change/alter of the profile of the project/programme?

39. What factors do you think influenced the success/failure of the project/programme?

40. Did you plan for scalability?
   □ Yes
   □ No

41. If Yes, did you achieve? If No, what were the reasons?

42. How do you want to achieve program sustainability (funding, government, community)?

43. If this project/programme was to be handed to the MoH, what do you think it is needed for the project/programme to succeed?

Thank you!
Annex 4: Questionnaire for Paper 5 (for healthcare workers)

A. Personal information
   1. Role in the project/programme

   2. Gender:
      □ Male
      □ Female

   3. How many years of work experience do you have in the mHealth area?

   4. How long did you work in the project/programme?

B. About the project/programme
   5. What is the name of the project/programme?

   6. Provide a description of the project/programme.

   7. Provide a description of your role in the project/programme.

   8. Which mobile device was used in the project/programme?
      □ Mobile phone
      □ Tablet
      □ PDA
      □ Other: ___

   9. What type of service is/was offered?
      □ Text message (SMS)
      □ Voice
      □ Multimedia message service (MMS)
      □ Data
      □ Other: ___
10. In which mode did/does your solution operate (offline, online mode, one-way, two-way)?
   □ Online
   □ Offline
   □ One-way communication
   □ Two-way communication
   □ Other: ______

11. Where was/were the implementation site(s)?

12. Did/Do you face any challenges/difficulties when using the system?
   □ Yes
   □ No

13. If Yes, what challenges/difficulties did/do you face?

14. If Yes, how did/do you overcome (or is overcome) the challenges/difficulties?

15. Do you think the project/programmed succeeded/failed?

16. What factors do you think influenced the success/failure?

Thank you!
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