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A sustainable and affordable support system for rural healthcare delivery

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ABSTRACT

In developing countries, especially where a large proportion of the population still resides in rural areas, healthcare access and delivery are often poor, and can potentially benefit from innovative service models and supporting technologies. In these rural areas, the challenges of healthcare quality are many, ranging from poor infrastructure, low literacy, poverty, to inadequate monitoring of patients with chronic or serious diseases. The myriad of challenges requires innovative solutions that are affordable, robust and sustainable over time. Furthermore, due to special characteristics of such rural areas and their inhabitants, any healthcare solution should embed a decision support mechanism to prevent basic medical errors and negligence. In this article, we first discuss a healthcare delivery model (home-based healthcare) in displaced rural areas of South Africa, and then we propose a patient monitoring system for supporting the model using Unstructured Supplementary Service Data (USSD) technology. The proposed system is decision support driven in that it supports medical staff (nurses, doctors) to decide on the course of intervention or further treatment based on the vital signs of the patients that are tele-monitored on a regular basis. This patient monitoring system facilitates patient information flow from home-based care workers to a local clinic or hospital, where the information is presented on a desktop computer used by clinic nurses and doctors for monitoring the patients' health and ultimately speeding up decision making. The proposed system is tested through a prototype, which is applied in practice and generates data for evaluation.

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1. Introduction

The current global healthcare expenditure has grown into an economic sector exceeding 5-trillion-dollars [38,39] with most of the industrialized countries spending well over 10% of their GDP on healthcare (in the USA it is as high as 16%) and developing countries (e.g., South Africa) making healthcare a national priority. Pivotal issues of 21st century healthcare are efficiency and accessibility. Efficiency is becoming a buzzword in discussion with both healthcare managers and decision makers. Behind the term there is enormous complexity; from healthcare processes management to decision making, policy, supporting technology, innovation, and socio-cultural and economic realities — all are interwoven and interrelated into the equation of efficiency. Pertinent to developing countries and specifically their rural areas, the efficiency challenge is dependent on the socio-cultural reality and economic affordance of the society. This requires innovative yet practical healthcare delivery models and sustainable supporting technologies that can improve the accessibility of healthcare in a rural context. In the following section we will discuss how, within the local rural socio-cultural and economic context, healthcare can be improved. In particular, the determinants of better healthcare in rural areas can become a model with supporting technology that are adequate given limited resources, affordable, robust, and sustainable while ensuring an acceptable level of quality in rural areas, which often have unique characteristics.

Displaced rural areas in South Africa are the result of the country's political past where black communities were often obliged, due to the government's apartheid policies, to live in isolated mostly rural areas far from the main employment or service centers. These displaced rural areas form the backdrop to this study as the case study area is also located in such an ex-homeland area. Although the apartheid system was dismantled areas such as these remain part of the landscape and settlement reality and are often characterized by high levels of poverty, whilst also experiencing poor access to basic facilities and services. Populations of such rural areas often have a lower life expectancy and there is a higher incidence of infectious and chronic diseases. Life expectancy in South Africa is 47 and 49 years for males and females respectively [37], and the estimated prevalence of HIV infected adults is 18.3% [33]. These conditions together with other stressors restrain economic growth and development in rural communities and also affect rural healthcare delivery. Rural hospitals and clinics are often poorly equipped and understaffed. Inhabitants of rural areas travel a significant distance (10–25 km) to visit a clinic or hospital, which are mostly walk-in visits without appointments. Commuting from rural areas to

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the nearest clinics is another impediment to the rural areas healthcare delivery [19].

The nature of healthcare provided (especially in the rural communities) is influenced by the available resources at health centers, and the daily demand cannot be predicted where a large proportion of the patients are walk-in patients. The result is that patients do not always receive all the needed attention and where clinics cannot provide a sufficient service, the patients are referred to the local- or regional hospitals. Patients can even return home without receiving any treatment. One of the main stressors in this environment is transportation; public transport is expensive and not always available — in some areas these services do not operate due to poor road conditions. Private transport is only available to a few and other residents pay if they utilize (hire) such private transport. According to the National Travel Household Survey [12], walking and cycling make up 23% of the modal share, that is, a significant group of commuters walk and cycle to work. It has been indicated that 53% of the rural population rely on walking long distances to get to essential services and the most affected category is low-income households. Private car ownership in rural areas is 43 per 1000 of the population which is very low compared to urban and metropolitan areas (168 and 136 respectively). Transport availability and expense mean that patients could sometimes walk long distances to the local clinic. Overall these factors make accessing healthcare difficult, time consuming and costly. This also negatively affects the health of patients who have no option but to use these available health facilities. To overcome some of these constraints an innovative and simple model of healthcare has developed specifically in displaced rural communities. Volunteers from within communities, mainly woman have created what is known as home-based care (HBC) [21]. By providing a care service to patients within the comforts of their homes, home-based care transcends the former boundaries between patient and clinician [35]. The strong tradition of Home-based Care, also referred to as informal healthcare, has become increasingly important, but also threatened to implode under its severe strains [22]. One critical challenge in home-based healthcare is the decision of healthcare caregivers to refer or help to transport a patient to a clinic or hospital. Volunteers report on the conditions of their allocated care patients during interactions with medical personnel at the clinic. These reports are in person but might not take place every day (especially if the care workers work far from the nearest clinic). These interactions, which are intended to update the medical personnel in the clinics and hospitals on the status of the patients, have the format of workshops or meetings, where the caregivers (volunteers) report the latest medical records. The care workers do not make medical decisions as they do not have medical training — they serve as the eyes/ears of the medical staff at the clinic and act upon their recommendations or instructions [17].

In this article, we discuss a solution developed and a prototype tested — a decision support system (DSS) based on tele-monitoring of patients. The proposed DSS helps the nurses and doctors gain more frequent updates of the (home-based) patients' conditions as reported through a set of vital signs. The system can also speed up decisions for further treatment at either the clinic or hospital. This tele-monitoring DSS allows the clinic nurses and doctors to provide better (and faster) healthcare and to effect a more efficient utilization of resources. This solution was made possible partly by the ubiquity of cell phones and mobile technology in rural areas, which created certain advantages and opportunities for the development of this system.

As [32] affirms, accelerating development by skipping stages in the development trajectory (also known as leapfrogging) holds big opportunities for developing rural areas. The most well-known example of leapfrogging is the rapid expansion of cell phone usage in the developing areas of the world, thereby avoiding the installation and use of landlines, a technology that has been used for decades in the Western world. [28] argues that the use of Information and Communication Technologies (ICTs) in developmental activities can considerably enhance rural development. However, according to [14] one-third of all ICT projects in rural areas are total failures and one-half are partial failures, leaving little room for success. Apparently, ICTs are not always easily adapted to fulfill the role of developmental accelerator. Mobile ICT tools have the following properties that enable their implementation and use in such challenging contexts; the infrastructure is relatively inexpensive, is often available even in rural areas, although the population is mostly poor, many either own a cell phone, or have access to one through friends or family, and developing mobile services is not overly expensive as compared to for example landlines. Critically, developing a mobile service that is appropriate, robust and sustainable in these rural environments has proven to be difficult. [5].

While the current literature on healthcare, healthcare models, and healthcare ICT presents a plethora of studies addressing different aspects of healthcare in developed countries, rural healthcare research has not received as much attention. This is especially relevant in countries where there are areas with large rural populations. This is a promising research direction, which requires significant scientific attention. Our research challenge therefore is to explore how ICT service systems can support the South African informal healthcare (home-based healthcare) decision processes in rural areas and to develop and test a robust and sustainable prototype of an ICT-based healthcare delivery model. The proposed solution resulted in a tele-monitoring system, which facilitates exchange of patient information between caregivers and clinic staff. Of equal importance in this research is understanding the socio-cultural and economic context of the problem and the related design challenges. The prototype of the tele-monitoring system is the result of joint research between Delft University of Technology (Netherlands) and the South African Council for Scientific and Industrial Research (CSIR). This study was driven by a real world problem and the system development was carried out in a period of seven months of fieldwork in addition to desktop research conducted throughout the project. The research is based on a design science approach, modified to deal with the specific design requirements for design for development.

The remainder of this paper is structured as follows: in part one we discuss the socio-cultural and economic context, which sets the stage for the research carried out and the results presented in this article; in part two we discuss the underlying theoretical foundation on which the presented research is based, which also includes the research objective, challenges, and methods used; in part three we relate the research rigor and relevance to the object of design (DSS for home-based healthcare) and the way the requirements were gathered for the design purpose; in part four the proposed solution is discussed, which also constitutes the core of this article; in part five the designed solution is evaluated and in the concluding part we discuss the research findings, draw conclusions and give a future possible research outlook.

2. Socio-cultural and economic context

Historically, rural areas, especially in the developing country context, face isolation and have poor levels of access to services and facilities, often including healthcare services. This lack of access to services and facilities puts rural areas at a distinct disadvantage compared to many urban centers [39]. The result is often unbalanced development, social and economic injustice and divide, which is common throughout the region [26]. Because of past policies, rural South Africa also has high-density population areas and displaced settlements (often in the former homeland territories) where many people live below the poverty line. Present settlement patterns reflect the distortions and policies of the past, and South Africa is still characterized by high levels of poverty, especially in displaced rural areas [18]. Approximately 39% of South Africa's people live in rural areas [11]. Their incomes are constrained

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