Development of Electronic Medical Record Systems for Maternal Health Services in Rural Settings

An Action Research Study from Malawi

By

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Acronyms
ANC   Antenatal Care
AIDS  Acquired Immunodeficiency Syndrome
AR    Action Research
ART   Anti-retroviral Therapy
CBMNC Community Based Maternal and Neonatal Care
CSCW  Computer Supported Cooperative Work
DHIS  District Health Information Software
DHO   District Health Office(r)
DSD   Distributed Software Development
EMR   Electronic Medical Record
EHP   Essential Health Package
FANC  Focused Antenatal Care
FOSS  Free and Open Source Software
HIS   Health Information System
HISP  Health Information System Programme
HIV   Human Immunodeficiency Virus
HMIS  Health Management Information System
HSA   Health Surveillance Assistant
ICT   Information and Communication Technology
IS    Information System
IT    Information Technology
LMP   Last Menstrual Period
MCH   Maternal and Child Health
MH    Maternal Health
MOH   Ministry of Health
OpenMRS Open Medical Record System
OPD   Outpatient Department
PD    Participatory Design
PMTCT Prevention of Mother to Child Transmission of HIV
PoC   Point-of-Care
TB    Tuberculosis
TTV   Tetanus Toxoid vaccine
Abstract

Implementation of Electronic Medical Record (EMR) systems within developing contexts has been increasing, as part of efforts to monitor and facilitate attainment of health-related Millennium Development Goals (MDG). However, these efforts have been concentrated in urban hospitals. This research was therefore conducted to understand how EMR systems can be developed for use in rural primary care settings in order to support attainment of the Millennium Development Goal of improving Maternal health. The empirical material has been obtained through an Action Research study conducted in Malawi from 2009 to 2013. Two Antenatal care EMR systems were implemented in two rural health centres. Data was collected using interviews, participant observations, and artefact analyses. Theoretically, this study focused on Participatory Design. A central objective was to understand the form of user participation that takes place when developing EMR systems in Developing country settings.

The findings show that discrepancies between protocols and work practices were apparent in the course of developing the EMR systems. These discrepancies were caused by several factors including high workloads, lack of medical resources, misunderstanding of the protocols by health workers, and client/patient practices. Balancing between the requirements from the protocols and the work practices was achieved through implementing the protocols at different levels, which are perceived as either weak or strong inscriptions of the protocols.

The study also reveals that there are challenges in participation with regards to users located in rural settings, due to limited availability of highly qualified health professionals in these contexts. Some of the users could not effectively participate in the design process, as they had limited knowledge on the Maternal health domain. This knowledge gap was supplemented through the involvement of other stakeholders including managers and other health experts. Thus, the study highlights the need for involving different types of stakeholders. In addition, the study identifies challenges of user participation, through mediators, in globally distributed software development projects, including difficulties in communicating requirements and lack of decision-making power in prioritisation of requirements. These challenges resulted in implementation of an EMR system with missing functionality, thereby frustrating the users. Thus, the study proposes strategies for enhancing participation in such distributed projects.

In addition, the findings reveal that clients are important stakeholders; therefore, clients should be viewed as cooperative actors in healthcare work. This implies that EMR system development processes need to pay attention to client-related aspects when designing EMR systems.

This thesis makes contributions to Health Informatics research in Developing countries. It provides insights on the nature of healthcare work in rural settings and highlights the role of clients. It also provides insights on effects of EMRs on Antenatal care work, and on appropriate EMR designs principles and strategies for rural contexts. The thesis also contributes to Participatory Design research in Developing countries by providing insights on the challenges of participation when developing EMR systems for rural contexts and participation challenges in globally distributes software development projects.
1 INTRODUCTION
This chapter introduces the topic of this research and provides an overview of the issues presented in this thesis. Firstly, the background to the research is presented, which includes the research problem, and personal motivation for conducting this study. The second section introduces the reference disciplines of this research. The third section presents the study objectives and research questions addressed in this thesis. Brief details of the research context and the research approach adopted are then presented in the fourth section. In the fifth section, the findings and contributions of the research are summarised. Lastly, an overview of the thesis structure is provided.

1.1. Research Background and Problem Area
Information and Communication Technologies are being implemented in healthcare settings with the belief that they can contribute to improved efficiency, access and quality of healthcare services (Dzenowagis & Kernen, 2005; WHO, 2012). Among these technologies, Electronic Medical Record (EMR) systems are recognised as one of the prime transformers of healthcare and a central element in Health Information Systems (Chetley, 2006; Fitzpatrick & Ellingsen, 2012; WHO, 2012). From a care perspective, EMR systems are expected to: improve the accuracy of patient care information recorded in health records; support clinical decision-making; and improve accessibility of patients’ healthcare information for continuity of care over space and time (Car et al., 2008; Chetley, 2006; Douglas, 2009; Fitzpatrick & Ellingsen, 2012). From a managerial perspective, EMR systems can generate health care statistics which are crucial in the management and planning of health services, thereby improving the quality of routine health data in health systems (ibid.).

The implementation and use of EMR systems in Developing Countries has been explored for more than a decade and reported benefits of using this technology have included reduced waiting time for patients, reduced medication order errors, guiding healthcare protocols and simplified generation of mandatory reports to higher authorities (Douglas, 2009; Fraser et al., 2005; Rotich et al., 2003). Due to low healthcare budgets in Developing Countries, the use of Free and Open Source Software (FOSS) is particularly advocated for as a strategy to eliminate licensing costs for sustaining the systems (WHO, 2012). This has resulted in the development of various free and open source EMR systems (Fraser et al., 2005). Despite these efforts, the implementation and use of EMR systems in Developing Countries remains limited (WHO, 2012; Were et al., 2010a). Furthermore, existing implementations are biased towards hospitals.
in urban areas leaving rural primary care facilities marginalised from benefiting from this technology (Piette et al., 2012). Ironically, the majority of the population in Developing Countries, like Malawi, live in rural areas and obtain healthcare services from rural primary care facilities (NSO, 2012). Therefore, it can be expected that implementing these technologies in rural primary care facilities would serve and benefit a bigger population (Singh et al., 1997).

Primary care facilities are the focal point for provision of basic public health and clinical services bundled as an Essential Health Package (EHP). Although the interventions included in the EHP vary across Developing Countries, the services broadly cover the areas of maternal and child health, communicable diseases, basic curative care, Environmental health, health education and communication (WHO, 2008). The provision of these services in rural health facilities is challenged by various factors such as poor basic infrastructure (i.e. electricity, transport, telecommunication, buildings and medical equipment), shortage of essential drugs and medical supplies, low staffing levels and low education levels (Douglas, 2009; Fraser et al., 2005; ITU, 2008; Sood et al., 2008). As a result, the quality of healthcare services in rural areas is considered sub-standard and ineffective (Mueller et al., 2011). For instance, Kinney et al. (2010) report that Maternal mortality is consistently lower in urban areas than in rural areas. In addition to these problems, ICT literacy is low among the health providers, and there is lack of ICT expertise in these rural areas. All of this makes implementing ICTs, such as EMR systems, in rural primary care facilities a more challenging endeavour (Martinez et al., 2002).

Nevertheless, if attempts are to be made to bridge the digital divide between urban and rural areas, and make progress towards e-health agendas, it is necessary for Developing Countries to strategize on how EMR systems can be implemented in rural primary care facilities amidst these challenging conditions. Some researchers have already identified solutions to address some of the infrastructural challenges in rural contexts by using, for example, renewable energy technologies such as Solar power, Windmills, and Power over Ethernet together with low-energy consumption hardware (Douglas, 2009; Martinez et al., 2002). In addition, with rapid diffusion of mobile phones in rural areas, the use of mobile technology to support health services is advocated for (United_Nations, 2007; Vital_Wave_Consulting, 2009).
A central challenge in the implementation of EMR systems is limited use among healthcare providers (Were et al., 2010a). The problem is not unique to Developing Countries as previous studies from western countries also identified limited adoption and use of EMRs among health professionals (Berg, 2001; Boonstra & Broekhuis, 2010; Tomasi et al., 2004). Thus, integrating use of EMR systems within healthcare service provision is, in general, a challenging task (Fitzpatrick & Ellingsen, 2012). Such limited use is, in part, considered as one of the reasons why EMR systems have not been able to achieve some of the expected benefits. For instance, in the context of Developing Countries where providers with less training are providing services, researchers have argued that limited use of EMR systems hinders the realisation of the positive impact that protocol guidance and decision support features can add to patient-level clinical care (Tomasi et al., 2004, Douglas, 2009; Mamlin et al., 2006).

Several factors have been identified as contributing towards this limited use, including lack of computer skills, complexity of the systems, and lack of good user interfaces (Boonstra & Broekhuis, 2010; Fraser et al., 2005; Tang & Patel, 1994). However, Weiderhold & Shortliffe (2001) indicate that many of the impediments can be avoided by involving users in system development process. This implies that how the development process unfolds is crucial in determining emergent use of EMR systems among healthcare providers.

Unfortunately, existing literature on EMR systems in Developing Countries have mostly focused on identifying appropriate technical designs for EMR systems and objective quantitative evaluations, with limited details on their development processes. Therefore, studies are lacking that analyse and discuss EMR development processes in the context of Developing Countries (Fitzpatrick & Ellingsen, 2012). As a result, there is limited understanding of EMR development processes in these contexts, including the associated challenges faced, and the appropriate/potential strategies (Scholl et al., 2011). Therefore, the aim of this study is to understand EMR development processes in the context of a Developing Country.

My motivation to conduct this study began as a result of a course I attended in 2008 on Wireless Networking technologies in Developing Countries. Working as a network administrator within the Malawi Government, the growth of these technologies seemed to present an opportunity for implementing networking technologies in rural settings of the
country. During the course I learnt that this technology had actually been implemented in a few semi-urban health centres in Malawi with an intention of improving communication among health facilities using Voice over Internet Protocol (VOIP) services, as well as providing healthcare workers with internet and email access. I was, therefore, curious to find out how this technology was being used by health workers in those facilities. However, a site visit to one of the health centres revealed that the technology was not being used by the health workers at all. This made me realise that it was not enough to have the infrastructure, but it was important to have relevant applications for the users and to establish the relevance and use among the health workers. Therefore, I was motivated to conduct the study in order to find out the appropriate ways of implementing such ICT-based systems, which will ensure that these systems are relevant and useful for the intended users, and that they are actually integrated into health service work practices.

1.2 Reference Disciplines
This study mainly relates to two research disciplines, Health Informatics and Participatory Design. Below, I present briefly each of these disciplines and how the study relates to them.

1.2.1 Health Informatics
Health Informatics is concerned with the application of ICT to support healthcare (Conrick, 2006). Health Informatics research strives for the collection of generally applicable knowledge that can be used within the healthcare domain (van Bemmel & Musen, 1997). The objectives of the discipline are: to contribute to high-quality, efficient healthcare, and to the quality of life; and to the progress of science (Haux, 2014). Accordingly, the outcomes of Health informatics research projects should be relevant to the above objectives.

In western countries, the application of ICT in healthcare dates back more than 50 years and it has significantly changed healthcare, such that Haux (2010, pg.601) writes:

“We can hardly imagine diagnostic procedures without, for instance, diagnostic imaging tools such as computer tomography, or therapeutic actions without the software that checks for medication interactions or uses computer-assisted tools for surgery, or for accessing medical knowledge without, for instance, accessing knowledge bases on high-quality publications, and without accessing and recording patient data in electronic records as part of computer-supported hospital information systems. Just imagine medicine and health care without information and communication technology.”.
Sadly, in Developing Countries, it’s not so unimaginable. While much advancement has been made in healthcare due to ICT in the western world, similar applications of ICT in Developing Countries remain limited (Blaya et al., 2010). There is, however, a growing body of research in Developing Countries exploring the development and use of ICTs in healthcare (Blaya et al., 2010; Douglas, 2009; Rotich et al., 2003; Oluoch et al., 2012). This study falls within Health Informatics studies in Developing Countries and aims to contribute to knowledge on the challenges and strategies in developing EMR systems for use in rural primary care settings.

### 1.2.2 Participatory Design

Participatory Design (PD) represents an approach towards computer-based systems development whereby the future users of the system play a critical role in designing it (Bjerknes & Bratteteig, 1995). This is influenced by notions of user empowerment, resulting from a workplace democracy movement, but also pragmatic reasons to improve the knowledge upon which systems are built (Schuler & Namioka, 1993).

Several IS studies from Developing Countries have argued that user participation is an important requirement in the development of information systems (Byrne, 2004; Korpela et al., 1998; Mursu, 2002). However, low education and IT literacy levels among expected users in these contexts are known to pose challenges to user participation (Kimaro & Titlestad, 2008). Heeks (1999), therefore, argues that in some of the IS projects in Developing Countries, participation is not a viable technique. However, participation is not a homogenous concept, but is interpreted and applied in different ways (Cavaye, 1995). It is therefore important to understand the nature and forms of participation that take place in Developing Countries. This study aims to provide an increased understanding of the nature of user participation in the development of EMR systems for use in a Developing Country context.

### 1.3 Research Objective and Questions

The overall objective of this research is to explore how EMR systems can be developed for use in rural primary care settings of a Developing Country, Malawi. There are two aspects to achieving this objective. One aspect involves examining the development process to understand the nature of participation, including the challenges and strategies in the development process. Another aspect involves examining the artefact developed, i.e. the EMR system, to assess the appropriateness of the designs for use in rural primary care settings. Using Maternal health as one of the services provided in rural primary care settings, this
research particularly focuses on how EMR systems for Maternal health services can be developed for such settings.

In light of this, the research seeks to answer two main questions. The first research question relates to the design of EMR systems for use in rural settings and is indicated as:

*RQ1:* What design principles and strategies support the use of EMR systems in the provision of Maternal health services in rural primary care settings in Malawi?

The second research question relates to the issue of user participation in the development process and is expressed as:

*RQ2:* What is the nature of user participation in the development of Maternal health EMR systems for use in rural primary care settings?

### 1.4 Research Context and Approach

This study was undertaken as part of a collaborative project on improving access and quality of Maternal healthcare in Sub-Saharan Africa, funded by the Norwegian Programme for Development, Research and Education (NUFU). The collaborating institutions were University of Oslo, University of Malawi and University of Dar es Salaam. One of the objectives of this collaborative project was to improve the Health Information System to enable appropriate monitoring and evaluation of Maternal health services in health institutions. The study reported in this thesis was conducted primarily within the Malawi public health system.

I have adopted a qualitative research methodology with an interpretive perspective. Interpretive IS research is concerned with understanding the social processes by which an information system is developed and construed by people, and through which the IS influences and is influenced by its social setting (Oates, 2006). This was considered appropriate for investigating the social processes of developing EMR systems, as well as their use in rural primary care settings in Malawi.

This research has adopted an Action Research strategy in trying to understand how EMR systems can be developed to support Maternal health services provision in Malawi. Action Research is grounded in practical action aimed at solving a particular problem whilst simultaneously contributing to knowledge (Baskerville, 1999; Davison et al., 2004). This was considered an appropriate method for me, as I was interested in participating in practical action towards solving the digital divide between rural and urban contexts. In addition, the
type of learning from Action Research represents enhanced understanding of complex socio-organisational problems (Baskerville, 1999). A longitudinal study of EMR systems development was conducted, starting from 2009 up to 2013.

1.5 Findings and Contributions

1.5.1 Findings
The empirical findings of this research are presented in the following six papers.


Paper 4: Chawani M.S., Kaasbøll J., & Finken S. Stakeholder Participation in the development of an Electronic Medical Record system in Malawi. Accepted for *Participatory Design Conference, 2014*.


Paper 6: Chawani M.S. A cross-case analysis of the effects of EMR deployment on Antenatal Care Services in Rural Health Centres in Malawi. *Submitted to Journal of Health Informatics in Africa*.

1.5.2 Contributions
The thesis contributes to Health Informatics research in Developing Countries. In a predominantly positivist research tradition, this thesis provides an interpretive analysis of
EMR systems development processes and their use in Maternal health services in rural primary care settings in Malawi. Through this analysis, it identifies challenges in the development process and use of EMR systems which relate to contextual factors in such settings. It also identifies design principles and strategies that support use of EMRs in the provision of Maternal health services in rural primary care settings.

The thesis also contributes to Participatory Design research in Developing Countries. The thesis provides an understanding of the forms of participation among different stakeholders during EMR systems development processes. Through this, the thesis identifies challenges of participation for users in rural primary care settings, as well as challenges for designers. It further proposes strategies that can be employed to address the identified challenges.

1.6 Thesis Structure
The rest of this thesis is organised as follows. Chapter two presents related work from the reference disciplines and the theoretical framework guiding the research. Chapter three provides the context of Malawi. This includes a general overview of the country profile, the health system, Maternal health services and the Health Information System. Chapter four presents the research methodology adopted in the study, which includes the philosophical perspective, research strategy, data collection methods, data analysis approach, and ethical considerations made. The chapter also presents my reflection on the methodology. Chapter five summarises the findings of the research, which have been presented in the papers forming part of this thesis. Chapter six is a discussion of the findings which is centred on answering the research questions. Chapter seven summarises the research contributions and proposes areas for future research.
2  RELATED WORK & THEORETICAL FRAMEWORK
This chapter presents previous related work and the theoretical framework for this thesis. The first section presents an overview of the Health Informatics discipline. This is followed by a review of literature specifically on Electronic Medical Record systems. The third section presents related work from the Participatory Design research tradition. The theoretical perspective adopted in this study is presented in the fourth section. The chapter concludes with a summary which provides an overview of the conceptual framework for this thesis.

2.1  Health Informatics
Health Informatics is a discipline concerned with the application of Information and Communication Technology to support healthcare (Conrick, 2006). It is defined as “a combination of computer science, information science and health science designed to assist in the management and processing of data, information and knowledge to support healthcare and healthcare delivery” (Conrick, 2006, pg.4). The term ‘medical informatics’ is used as an alternative to health informatics; however, it is noted that others perceive medical informatics to be focused on the application of IT in medicine and biology only (Shortliffe & Blois, 2001). In this thesis, I consider the terms to be synonymous.

Health informatics research strives to collect generally applicable knowledge that can be used within the healthcare domain (van Bemmel & Musen, 1997). The aim is to develop and assess methods and systems for the acquisition, processing, and interpretation of patient data with help of knowledge that is obtained in scientific research (ibid.). The objectives of the discipline are to contribute to high-quality, efficient healthcare, quality of life; and to the progress of science (Haux, 2014). It is predominantly a positivist tradition rooted in quantitative research approaches (Greenhalgh et al., 2009). However, publications of interpretative, qualitative studies incorporating insights from social sciences are increasing within the discipline (Berg et al., 2003).

Health informatics is highly inter- and multidisciplinary and therefore, has many facets (van Bemmel, 2008; Haux, 2014). It is considered an engineering discipline that builds tools to support many facets in organising care and healthy living; and an organisational discipline that helps to change processes and organisations (Haux, 2014). It is also perceived as a modelling discipline that focuses on creating models of healthcare processes, and an empirical discipline requiring nature and institutions (ibid.). Due to its multidisciplinary nature, there is a wide range of research topics covered within health informatics. However, Schuemie et al.
(2009) indicate that the research can be categorised into three research fields: 1) the organisation, application and evaluation of health information systems; 2) medical knowledge representation; and 3) signal and data analysis. This study falls within the field of Health Information Systems (HIS).

Within HIS research, there are several areas where the application of ICT is pursued, such as public health, patient care (i.e. both primary-care and specialised clinical care), personalised care/consumer health, hospital management, health management, health education, and health research (Ayres et al., 2006; van Bemmel & Musen, 1997; Shortliffe & Perreault, 2001; Schuemie et al., 2009). In this thesis, the interest is on patient care information systems that are concerned with the use of ICT in providing care to patients. The specific focus is on primary care. Branger & Duisterhout (1997) indicate a typical primary care IS in a western setting contains functions for: practice organization and administration; care provision; and statistical overviews and research.

There are different types of patient care information systems and these include Electronic Medical Record (EMR) systems, Patient registration systems, Clinical Decision Support systems (CDSS), Computer-based Provider Order Entry (CPOE) systems or Medication systems, Pharmacy Information Systems, Laboratory Information Systems, Telemedicine systems, Radiology Information systems (Ayres et al., 2006; Schuemie et al., 2009; van Bemmel & Musen, 1997). Though they are perceived as different types of systems, it is often the case that some of them (e.g. EMRs, CDSS and CPOE) are integrated within one application (van Bemmel & Musen, 1997). Nevertheless, Electronic Medical Records are the core clinical application, as they are central to many patient care services (Car et al., 2008); some even consider them to be the ‘holy grail’ of health informatics (Boulos & Bjorn, 2010). Accordingly, EMRs are the focus of this thesis.

2.2 Electronic Medical Record Systems
Electronic Medical Records (EMR), Electronic Patient Record (EPR), Computer-based Patient Record (CPR), and Electronic Health Record (EHR) are all terms that have been used interchangeably to refer to a collection of electronically maintained information about an individual’s health status and health care (Tang & McDonald, 2001; Heard, 2006). However, EMR, EPR and CPR often refer to records implemented at a single or several related healthcare institutions; whilst EHR is often associated with a record containing all personal health information over the person’s lifetime, entered (or accepted) and accessible by
healthcare providers distributed in multiple sites, including all ambulatory care settings at which the patient receives care (Heard, 2006; WHO, 2006). In this sense, the EHR is an integrated, centralised record, which is the ultimate goal that national health systems are striving for (Fagan & Shortliffe, 2001; Heard, 2006). In recent years, another related term has emerged ‘Personal Health Records’ (PHR), which is similar to EHRs, but is managed by the individual instead of health institutions (Sood et al., 2008). However, this study does not include PHR.

Medical records, whether in paper or electronic form, serve multiple purposes within healthcare. They are meant to: create a basis for the historical record; support communication among providers; anticipate future health problems; record standard preventive measures; identify deviations from expected trends; provide a legal record; and support clinical research (Shortliffe & Barnett, 2001). However, paper-based medical records are known to fall short in several ways: they may be inaccessible when in use by someone else or if misplaced; there may be missing data in the records due to oversight of the health provider; the data may be difficult to read; the records grow so large over time; there is redundant recording of data in different locations; and it is tedious to extract data for clinical research (ibid.). Electronic Medical Records are considered a solution for these shortfalls in paper-based records.

2.2.1 Benefits/Effects of EMRs

EMRs are perceived to have direct and indirect benefits for healthcare in several areas. EMRs are expected to have positive effects on access to data and the quality of the data since they can be accessed whenever needed and the documentation is more legible (Shortliffe & Barnett, 2001). A computer can also improve completeness and accuracy through validation checks on data entered, and prompts on missing data. In addition, EMRs are expected to improve the efficiency of the care process in terms of time-savings, as well as improving the quality of care rendered through, for instance, increased adherence to protocols and reduced medical errors (Car et al., 2008; Chaudhry et al., 2006; Holroyd-Leduc et al., 2011). Furthermore, ultimately, EMRs are expected to improve the clinical outcomes in terms of the health status; however, it is challenging to evaluate this as there are other factors that influence clinical outcomes (Holroyd-Leduc et al., 2011; Blaya et al., 2010). Apart from these benefits on patient care, secondary uses of EMR data in administration, disease surveillance, managing and monitoring of the services are also expected to improve health services (Car et al., 2008). Other expected benefits are reduced financial costs over time through savings in
e.g. billings, transcription costs, patient cycle time, utilisation of services and support staff salary (Chaudhry et al., 2006; Holroyd-Leduc et al., 2011).

Nevertheless, studies have also reported negative effects of EMRs. For instance, despite EMRs improving access to records, it may be hard to search and efficiently review the information in the record (Holroyd-Leduc et al., 2011). Furthermore, EMRs could impose additional administrative work tasks on already heavily burdened health providers (Ash et al., 2004; Tang & McDonald, 2001). EMRs may also foster errors in the processes of entering and retrieving information, and in communication and coordination (Ash et al., 2004). In addition, Car et al. (2008) indicate that the quality of data in EMRs varies due to sociotechnical factors surrounding individual users. Other concerns with EMRs have included issues around privacy and confidentiality, hardware problems, system failures, time required to learn how to use it, and decreased patient-physician interaction (Tang & McDonald, 2001; Holroyd-Leduc et al., 2011). Thus, the studies reveal mixed effects of EMRs on care processes and outcomes. The benefits of EMRs are, therefore, considered to be dependent on the quality of the implementation process and the extent to which decision support is integrated (Car et al., 2008). Tang & McDonald (2001) identify four specific factors that benefits depend on, these are: comprehensiveness of information; duration of use and retention of data; degree of structure of data, and ubiquity of access. Intrinsically, these issues relate to the system’s functionality and design, and the development process. These issues are examined in the subsections that follow.

2.2.2 EMR systems’ Functionality

Electronic Medical Records are not simply an electronic version of the paper record; rather they are part of a comprehensive system, which has additional information management tools (Tang & McDonald, 2001). The scope of functionality in EMR systems varies in different contexts. However, Tang & McDonald (2001) indicate that a comprehensive EMR system should have the following functional components: an integrated view of patient data, clinical decision support, clinician/provider order entry, access to knowledge resources, integrated communication support and analysis of aggregated data (Tang & McDonald, 2001).

An integrated view of patient data stems from the provider’s need for a historical overview of the patient’s health status. This creates a need for exchange of health information between different systems for continuity of patient care among different healthcare service providers (Weiderhold & Shortliffe, 2001; Conrick et al., 2006). However, achieving such integration is
not a simple task as it requires implementing different types of standards (ibid.). There are four main types of standards required: system standards, vocabulary standards, messaging standards and security standards (ibid.). Hammond & Cimino (2001) also state that there is need for standardized identifiers for individuals, healthcare providers, health plans, and employers, so that they can be recognised across systems.

Decision support functionality is considered to be important when dealing with decisions related to diagnosis and to therapy (van Bemm el et al., 1997). Computers may assist in the diagnosing of a disease based on the individual patient data, and in determining the best treatment based on evidence. The evidence may be based on, for instance, clinical guidelines and care protocols (ibid.). Decision support functionality is considered most effective when provided at the point of care where the provider is formulating his/her assessment of a patient’s condition and is making ordering decisions (Tang & McDonald, 2001). It is, however, recommended that the applications should allow the provider to override a system-provided recommendation and choose an alternative action. Reminders and alerts are some of the forms of decision support. The provider order entry functions relate to ordering of laboratory tests, prescription of drugs or creating referrals to other allied health services (Ribbons, 2006). The use of decision support functions in these activities is considered essential, as already explained. Furthermore, access to knowledge sources is another functionality that is considered important for supporting the decision-making for a particular patient (Tang & McDonald, 2001).

The functionality of supporting communication among different healthcare providers is considered important with distribution of the care process (ibid.). Thus, communication tools that allow for sharing information (e.g. lab results) within the EMR are advocated for. Communication with a patient, for instance, through email, is also another aspect, which is considered important (ibid.).

In developing the required functionality, there are several design issues that have been highlighted. These are presented in the next subsection.

2.2.3 EMR Design Issues and Principles
Primarily, for the benefits of EMRs to be achieved, it is required that the data should be structured and coded to a certain degree (Ginneken et al., 1997). However, entering structured data requires more effort from providers who are more accustomed to recording narrative textual data on paper-based records (ibid.). The effort required in entering data is one of the
reasons for limited use of EMRs by providers during patient consultations (Tang & McDonald, 2001). There are three data-entry methods than can be used: transcription of dictated or written notes, data entry from structured encounter forms, or direct entry at the point of care (ibid.). The most commonly used approach is data entry done by support personnel using structured encounter forms filled by the care provider (ibid.). For all methods, it is important for the user interface design and the physical input/output devices to be appropriate for the user’s requirements and work context (Patel & Kushniruk, 1997).

With regards to the user interface, a basic design principle in relation to navigation, layout, and colour is to Keep it Simple (KIS) (Guest & Conrick, 2006). Difficulty in navigation can lead to use of paper documents instead of the EMR. The use of symbols in EMRs is considered important for enabling quick access and enhancing usability (ibid.). In addition, incorporating different types of validity checks is recommended for error prevention during data entry. These include range checks, pattern checks, consistency checks and spelling checks (Tang & McDonald, 2001). Guest & Conrick (2006) further indicate that incorporating the following elements could assist in reducing or preventing errors: menu selection (as opposed to form fill-in); no alphabetical characters where numbers are expected; checks before proceeding with major actions; and feedback on errors.

In relation to layout, a design that appropriately groups information by function and reduces the overall information density on a screen is recommended (Guest & Conrick, 2006). Consistency in the layout and highlighting important information is also recommended (Ginneken et al., 1997).

Ginneken et al. (1997, pg.492) present the following design principles/attributes for health care user interfaces:

1. **Ease of use.** The system should be perceived by end users as easy to use and as leading to few user problems.
2. **Effectiveness.** The system should do what is functionally required by the users
3. **Ease of learning.** The users should be able to learn its operation within some specified time
4. **Ease of understanding.** The users should be able to develop a coherent model of the system.
5. **Predictability.** There should be consistency in input operations, option selection and presentation of output.
6. **User control.** The user should be able to control the interaction rather than being forced to follow a rigid computer-controlled dialogue.

7. **Robustness.** A high degree of robustness is required due to time pressures in healthcare settings.

8. **Adaptation to different user levels and styles.** There is need for flexibility to adapt to users, tasks and environments.

9. **Input flexibility.** Intuitive and flexible forms of input, suited to different types of users.

10. **Appropriate amount of output.** The system should not overwhelm users with large amounts of data that lead to cognitive overload.

11. **Adequate user help and error recovery.** On-line help should be available and error messages should indicate problems and constructively suggest solutions.

12. **Adequate response time.**

Furthermore, as indicated previously, confidentiality and privacy are central concerns in the use of EMRs, and therefore authentication and access control are important in the design of such systems (Guest & Conrick, 2006).

### 2.2.4 EMR Systems development

EMR systems development processes are essentially based on the general IS development life cycle, which involves phases of planning, analysis, design, implementation and maintenance (Strachan, 2006). Modelling of healthcare information needs is considered an important part of the development process that helps to understand healthcare activities (Frean, 2006). This involves defining the user’s needs and workflows in the process. However, it is a challenge to successfully document the design requirements that meet the needs of the users and the healthcare system in general (Strachan, 2006). Involving future users, i.e. the health workers, in the development process is one of the recommended strategies for ensuring the system meets their needs (Weiderhold & Shortliffe, 2001). This implies adopting a Participatory Design perspective to the development. I return to Participatory Design in section 2.3 of this chapter.

### 2.2.5 EMR systems in Developing Countries

EMR systems have been implemented in Developing Countries for almost a decade with most of the initial efforts driven by HIV treatment programmes (Fraser & Blaya, 2010). However, their use has expanded to support other care programmes such as Tuberculosis (TB) programmes, Immunisation, Maternal and Child Health, cardiac disease, and general primary care (Fraser et al., 2005; Fraser & Blaya, 2010; Kamadjeu et al., 2005; Rotich et al., 2003; Chi
et al., 2011; Singh et al., 1997; Douglas, 2009; Thompson et al., 2010; Waters et al., 2010; Castelnuovo et al., 2012; Ngoma et al., 2012; Anantraman et al., 2002; Were et al., 2010b).

The range of functionality in the EMR systems have included patient registration, visit data collection, tracking/monitoring patients and their treatments in the health programs, medication order entry, drug/supplies inventory management, appointment scheduling, decision support, statistics and generating reports. Decision support systems have specifically received more attention as a possible solution to the lack of trained clinical personnel, especially in rural areas of Developing Countries (Blaya et al., 2010). Furthermore, with the high adoption of mobile telephones in Developing Countries, there is an increasing interest on functionality to support communication with patients/clients (WHO, 2012). For instance, researchers have been exploring the use of SMS to communicate to patients, in specific health programs, about their visits, e.g. visit reminders, or merely health education messages (Blaya et al., 2010; WHO, 2012; United_Nations, 2007).

Evaluation studies have reported several benefits of EMRs, which are inline with the expected benefits in general. These benefits include:

- Improvement in the accuracy and completeness of data (Castelnuovo et al., 2012);
- Increased efficiency in terms of time saved in locating patient information and in producing monthly reports; reduced waiting time for patients, reduced provider time per patient and shorter visits in general (Rotich et al., 2003; Fraser et al., 2005);
- Improvement in the quality of care due to decision support functions within EMRs (Douglas et al., 2010; Fraser et al., 2005; Oluoch et al., 2012; Kamadjeu et al., 2005; Blaya et al., 2010).

Nonetheless, there are various challenges identified in the implementation and use of EMR systems in Developing Countries. These are discussed in the next section.

2.2.6 EMR Design and Implementation Issues in Developing Countries

There are several EMR design principles and implementation strategies that have been employed in Developing Countries. Some of the principles and strategies relate to the general EMR design principles presented previously, whilst others are meant to address specific challenges faced within developing contexts.

There are mainly two methods for data entry that have been employed in the implementation of EMR systems. The first method is the use of paper-based structured encounter forms
during consultations, which are then used to enter data in the EMR, as reported in (Oluoch et al., 2012; Kamadjeu et al., 2005; Rotich et al., 2003; Thompson et al., 2010; Were et al., 2010b). This is considered retrospective data entry, and the task is normally done by support staff, e.g. data clerks. The second method concerns direct data entry, which is done by the health providers at the point of care (e.g. Castelnuovo et al. (2012), Chi et al. (2011), and Douglas et al. (2010)). This implies real-time use of the EMR, referred to as Point of Care (PoC) or Provider-based EMR systems (ibid.). Some implementers have argued that when data entry is retrospective, it is most likely that the deficiencies of a manual registry are transferred to the computerized registry, such as transcription errors, leading to missing and inaccurate data (Douglas et al., 2010; Castelnuovo et al., 2012). It is also argued that retrospective data entry hinders realization of the positive impact that protocol guidance and decision support features can add to patient care (ibid.). However, others have argued that getting the data back into the hands of the providers through, for instance, clinical summaries from EMR systems, can still assist in patient care even when providers have no direct interaction with the computer (Mamlin et al., 2006; Were et al., 2010b).

The user interface design of EMR systems has been of concern in Developing Countries. Fraser et al. (2005) state that the interface is the component of a system which changes the most; therefore, it should contain minimal functionality to make it is easy to change. The need for flexibility in the design to accommodate informal practices and improvised data collection tools has also been identified (Ngoma et al., 2012). Therefore, the use of data-driven forms that can be easily generated is recommended (Mamlin et al., 2006). To further simplify the interface, Douglas (2009) adopted a wizard-like approach to capturing information whereby each screen was dedicated to collecting a single piece of data, rather than having multiple data entry fields on a single screen. In this way, large forms were represented as a series of steps/questions on each screen. In addition, the interface design is closely associated to the choice of the devices that will be used to interact with the EMR (Blaya et al., 2010). Due to low computer literacy among health workers in Developing Countries, the use of a touchscreen interface, rather than standard keyboard and mouse, is recommended (Douglas, 2009). The touchscreen interface is perceived to be easier to learn and to use (ibid).

A central challenge in Developing Countries has been the absence of national unique identification numbers for individuals (Piette et al., 2012). In addition, general literacy levels are low such that patients/clients are unable to write their own names and are unaware of the date of birth. This makes it challenging to uniquely identify individuals using the name and
date of birth. Thus, implementing patient registration systems that produce patient IDs has been considered an important component in EMR systems for continuity of care (Piette et al., 2012; Rotich et al., 2003; Douglas, 2009; Chi et al., 2011). The Patient IDs can be printed on label stickers or as patient ID cards that are kept with the patients (ibid.). Printing the IDs in form of barcodes has also been employed to simplify the searching of records, by using barcode scanners (Douglas, 2009). Apart from issuing IDs, search functionality with an algorithm that matches similar sounding letters (to avoid duplication due to inconsistent spelling) has also been implemented in some EMRs (Waters et al., 2010).

Another challenge in Developing Countries is shortage of qualified staff which leads to high workload for the available staff (Sood et al., 2008). Unfortunately, the phase-in period, when both paper and EMRs are used, is still necessary for the providers to gain confidence with the new system; and this may increase the workload and retard the workflow (Castelnuovo et al., 2012). Waters et al. (2010) propose incorporating time-saving measures in the design, for instance, by displaying a list of common treatments for a particular diagnosis, and by printing visit details entered electronically to avoid redundancy in recording.

Free and Open Source Software (FOSS) solutions are advocated for in Developing Countries due to limited healthcare budgets (WHO, 2012). FOSS is also considered appropriate for building software development capacity in Developing Countries (Seebregts et al., 2009). The Open Medical Record System (OpenMRS) is one of the most widely used open source EMR systems (Seebregts et al., 2009; Oluoch et al., 2012). Central for this system is the data model and concept dictionary, which is designed for scalability and flexibility (Mamlin & Biondich, 2005). The concept dictionary contains all diagnosis, tests, procedures, drugs and other general questions and potential answers. Coding of concepts in the dictionary is central, and the use of internationally recognized vocabulary standards, e.g. ICD-10 and LOINC, is advocated for, in order to enable interoperability with other systems (Fraser et al., 2005; Mamlin et al., 2006).

Developing Countries also face challenges of poor electricity and ICT infrastructures, which results in lack of reliable electricity and internet access (Lewis et al., 2012; ITU, 2008). In addition, there is often inadequate funding to support healthcare provision. Due to such challenges, issues relating to the hardware infrastructure have been of concern. Some initial EMR implementations deployed stand-alone systems in order to keep the implementation simple with minimal costs (Rotich et al., 2003). However, using one computer proved to be
challenging for the workflow. Therefore a networked system providing access to the EMR from multiple terminals was considered the logical design (Fraser et al., 2005). The EMR server may be hosted locally at the health facility or it may be offsite (ibid.). Due to lack of stable power and technical expertise in health facilities, implementers have argued for having the server hosted offsite (Fraser & Blaya, 2010). For instance, a city-wide network-based system with central data storage was implemented in Zambia to accommodate movement of patients from site to site during prenatal care (Chi et al., 2011). However, such an implementation requires stable and reliable network connectivity to the server, which might be challenging in rural settings. Nevertheless, others have been able to provide reliable internet access through satellite connection, though at a higher cost (Fraser et al., 2005; Waters et al., 2010). An alternative has been to allow offline storage of data locally when there is no connection, and upload or synchronize with the server later on (Fraser et al., 2005).

Regardless of whether the server is hosted onsite or offsite, there is still need for reliable power backup for the local devices due to frequent power cuts. In some cases, Uninterruptible Power Supplies (UPS) have been used for power backup (e.g. Rotich et al. (2003)); however, they are considered inadequate for prolonged power outages, which are common in Developing countries (Douglas, 2009). The use of generators has also been explored, but this is often challenged by lack of funds for procuring fuel (ibid.). Alternatively, the use of deep-cycle batteries, to power devices, has been implemented together with the use of low-power consumption devices (ibid.). The batteries can be charged from the electricity grid (if available) or from solar/wind power. In addition, the use of laptops as servers has been explored due to the built-in battery (Fraser & Blaya, 2010). Furthermore, the use of mobile devices for network and power independence is also increasing (ibid.).

Despite these acknowledged challenges and proposed design and implementation strategies, there is still a lack of in-depth understanding of social issues (such as the workflow redesign and human factors), which are involved in realising benefits from EMR systems (Chaudhry et al., 2006). Some of these issues have been analysed in the context of western countries (e.g. (Ash et al., 2004; Berg, 1999a; Boulus & Bjorn, 2010)); however, similar analyses are lacking in Developing Country settings. This thesis aims to provide such an understanding from a Developing Country perspective.
2.3 Participatory Design
Participatory Design (PD) is concerned with involvement of future users of a computer-based system in work activities during system development (Bjerknes & Bratteteig, 1995). The ultimate goal is for users and designers to work as full partners in design processes (Robertson & Simonsen, 2013). The motivations for introducing participation have varied in different contexts. In Scandinavia, where PD efforts originated, the aim of user participation was to increase workplace democracy; thereby ensuring that employees of an organisation were given the right to participate in decisions likely to affect their work (Bjerknes & Bratteteig, 1995). On the other hand, participation in the US was introduced as a response to a failure with traditional technical approaches to systems development (Greenbaum, 1993). Here, it was acknowledged that participation could overcome some of the failures by way of: improving the knowledge upon which systems were built; developing more realistic expectations; and reducing resistance to change (ibid.). Thus the emphasis was on usefulness and quality of the product, rather than workplace democracy.

The issues addressed within PD are considered to fall within three main areas: 1) politics of design; 2) nature of participation, and 3) methods, tools and techniques for carrying out design projects (Kensing & Blomberg, 1998). The politics of design deals with issues concerning distribution of power, which relates to the interests on workplace democracy (ibid.). The nature of participation is concerned with understanding forms of participation, which are required in order to bring about changes (ibid.). PD researchers have also developed practices that enable participation in form of PD methods (ibid.). A method is composed of tools, techniques and principles of organisation (ibid.). In this study, the main focus is on understanding the nature of participation; nevertheless, it is impossible to completely disregard issues related to power and methods in such an analysis.

2.3.1 Forms of Participation
User participation is interpreted and applied in different ways and hence, there are many ways to define and categorize participation (Bergvall-Kåreborn & Stålbrost, 2008; Cavaye, 1995). The most simplistic categorisation views participation as varying from direct involvement, where all parties affected by the system are involved, to indirect, where representatives serve in decision-making committees (Ives & Olson, 1984). Indirect participation has been common in distributed software development projects where users and developers are unable to meet. In such projects, the representatives have been viewed as mediators (Iivari et al., 2009). Issues concerning mediation are further explored in section 2.3.3 of this chapter.
Another way of classifying participation we find in Mumford (1981). She identifies three forms of participation, namely consultative, representative and consensus. The consultative is the lowest level of participation. Here, the bulk of design decisions are left to designers, who strive to ensure that the system is based on the users’ needs. Representative participation has a higher level of participation, whereby a design group consists of user representatives and designers, and the users have an equal say in any decision. Consensus participation attempts to involve all members of user departments continuously throughout the design process.

Cavaye (1995) provides another way of describing participation. She identifies six dimensions or attributes for describing user participation: type, degree, content, extent, formality and influence. These are presented in Table 2.1.

Table 2.1: Dimensions/Attributes of User Participation (Cavaye, 1995)

<table>
<thead>
<tr>
<th>Attributes of participation</th>
<th>Possible values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>All users, representatives of users</td>
</tr>
<tr>
<td>Degree</td>
<td>Advisory capacity, sign-off responsibility, part of team, full responsibility</td>
</tr>
<tr>
<td>Content</td>
<td>Technical design, social and technical design</td>
</tr>
<tr>
<td>Extent</td>
<td>Project definitions, requirements definition, building, testing</td>
</tr>
<tr>
<td>Formality</td>
<td>Formal, informal</td>
</tr>
<tr>
<td>Influence</td>
<td>Input ignored, contribution considered, input taken seriously</td>
</tr>
</tbody>
</table>

The type of participation is considered as the proportion of users that participate (ibid.). This is also associated with the different stakeholders and their roles (Bergvall-Kåreborn & Ståhlbrost, 2008). The degree of participation is defined as the level of responsibility that users may have during participation (Cavaye, 1995). However, this seems closely related to the dimension of influence, which Ives and Olson (1984, pg.590), whom Cavaye draws on, define as “the amount of influence the user has over the final product”. Influence is perceived as the effect of participation on the development (Cavaye, 1995). The content of participation relates to how users are involved in different aspects of the system design, i.e. either the technical or social aspects or both. Extent of participation looks at participation during different phases of the development process. Formality relates to whether the participation is formally organized using formal groups and team and holding discussions in official meetings, or whether it takes place through informal relationships, discussions and tasks.
Cavaye’s dimensions and attributes differ from Mumford’s classification in that they entail more specific details of participation. For instance, Mumford’s classification can be viewed as based on the dimensions of who participates, i.e. type, and the degree of participation. Cavaye’s dimensions have been considered a useful framework for analysing user participation. For instance, Lynch & Gregor (2004) used the framework to analyse user participation in the development of decision support systems in the Australian agricultural sector, noting that the effectiveness of user participation can vary across different types of systems. Through their analysis, they developed the construct of degree of influence on design, which was dependent on the type of user participation and the depth of user participation (ibid.). However, there are limited studies in PD that describe and discuss the forms and attributes of participation that take place within their projects and their outcomes (Bergvall-Käreborn & Ståhlbrost, 2008). Thus, one of the critiques on PD is its limited focus on the design outcomes (Balka, 2010; Puri et al., 2009).

2.3.2 Stakeholder types and roles in PD
Stakeholders are defined as people or groups of people having a stake in an information system (Avison & Fitzgerald, 2006). In PD and IS in general, this has often meant users of various kinds (Avison & Fitzgerald, 2006; Bødker et al., 2011; Larsson, 2006). However, Avison & Fitzgerald (2006) categorize stakeholders as: those on the organizational/business unit side, generically known as the users; those on the development side (e.g. programmers, designers), and those external to the boundaries of the organization (e.g. customers, shareholders, sponsors, society etc.).

Robertson & Simonsen (2013) define users as those who will interact with the technology being designed. These people also go by the name ‘end-users’ (Avison & Fitzgerald, 2006; Damodaran, 1996). In some cases, users have been considered to encompass senior management who may use the system’s output, and middle management who supervise the work affected by the system (Mumford, 1981; Cavaye, 1995). Managers and operational staff are often considered different types of users or user groups. It is recommended that each user type should influence decisions concerning design of the facilities they will use in the future, i.e. the ones that are relevant to them (Damodaran, 1996; Bødker et al., 2011). In deciding which users should participate, Bødker et al. (2004) recommend that they should have: knowledge of the relevant work domains; professional respect among their co-workers; and they should have enough time to participate in the project. Furthermore, Bødker et al. (2004) advocate a ‘principle of anchoring visions’, which promotes involvement of other staff
members so that they can keep tabs on design projects and have opportunities to provide feedback.

The role of managers was rather restricted in the early PD projects in that they were deliberately left out from design processes (Kensing & Blomberg, 1998). During that historical moment, PD efforts were particularly concerned with countering the privileged role ascribed to managers in system development (ibid.). Thus, within PD, managers have been assigned the responsibility of creating an environment that both fosters user participation and motivates subordinates to participate in design of future IT solutions (Damodaran, 1996; Bødker et al., 2004; Avison & Fitzgerald, 2006). This includes allotting staff, time, finance and information resources necessary for making user participation happen (ibid.).

Designers are considered responsible for the design projects, which includes planning and conducting the projects (Bødker et al., 2004). Koh & Heng (1996) also state that the ultimate responsibility of the functionality and usability lies with designers. It is further stated that it is not a designer’s job to resolve political conflicts that may emerge, but rather develop different design visions and assess their consequences for the affected parties (Bødker et al., 2004). Conversely, Johannessen & Ellingsen (2012) argue that designers or technology providers should be viewed as mediators in the design processes as it requires negotiations among many stakeholders. They further argue that the roles between designers and users are not automatically given or fixed, but depend on the mutuality of the relationships among the stakeholders.

Apart from users, managers and designers, the involvement of other types of stakeholders has been highlighted in recent PD literature (Oostveen & Van den Besselaar, 2004; Dalsgaard, 2012; Johannessen & Ellingsen, 2012; Simonsen & Hertzum, 2012). This is primarily due to an increased complexity in PD projects undertaken, which are more and more large-scale. For instance, in the development of an EPR system for a Danish hospital, Simonsen & Hertzum (2012) identify a range of stakeholders, such as politicians and strategists engaged in health care at national level; the vendor; the EPR unit; unit management, physicians and nurses. The multiplicity of stakeholders brings about challenges in terms of how different interests can be aligned. Simonsen & Hertzum (2012, pg.18) further state that the challenge for PD is “to argue how PD, with its direct involvement of end-users, is an effective means to manage, mesh and meet the needs of these different interests”. They propose a strategy for identifying and relating different stakeholders’ interests which can potentially be used to argue for a PD
approach that focuses on end-users’ work practices. Still, there are limited studies that characterise the interaction between various stakeholders within IS development processes and therefore more studies are needed (Larsson, 2006).

2.3.3 Participation in Distributed Software Development Projects
User participation can be challenging in software development projects where users and developers are highly distributed, e.g. across different physical locations, organisations, and/or application domains (Titlestad et al., 2009; Gumm et al., 2006; D'Andrea et al., 2008; Barcellini et al., 2008). For instance, geographical distribution may make it difficult for users and developers to meet, thereby reducing possibilities for frequent discussions and feedback (ibid.). In addition, organisational distribution of users may also bring forth challenges of different and contradicting system requirements (ibid.). The distribution of stakeholders is common, and high, in large-scale projects and in open source software projects (Oostveen & Van den Besselaar, 2004; Barcellini et al., 2008).

The use of online collaboration tools is one of the strategies used to enhance user participation in such Distributed Software Development (DSD) projects (Staring & Titlestad, 2008; Gumm et al., 2006; Barcellini et al., 2008). However, target users might not have the necessary computer equipment, internet connectivity, and competence to effectively participate using the online tools (Staring & Titlestad, 2008; Iivari, 2011). Thus, the use of mediators is considered essential in facilitating user participation in DSD projects (Titlestad et al., 2009; Gumm et al., 2006; Barcellini et al., 2008). For instance, in relation to a DSD project with users and developers located in various countries, Braa & Sahay (2013, pg.247) indicate “to what extent design is participatory will depend on how implementers mediate requirements between users and developers”.

Mediators are meant to bridge communication gaps by building linkages and providing ‘two-directional’ feedback between users and developers (Titlestad et al., 2009; Gumm et al., 2006; Tuovila & Iivari, 2007). Mediators play a similar role to key users who use software intensively and report first-hand experiences back to developers; but in addition, they pass feedback from developers to the user group (Gumm et al., 2006). Mediation requires that the mediators know the members of a development team and have regular exchange with them, and that developers provide ample feedback to the mediators in order for them to inform their user groups (Gumm et al., 2006). Mediators are also required to have skills and competence in different fields that are spanned, i.e. they should have knowledge about the users’ application
domain, and about the software to such an extent that they can specify new requirements to
developers (Braa & Sahay, 2013; Barcellini et al., 2008; Tuovila & Iivari, 2007). Therefore,
according to Tuovila & Iivari (2007), mediators are expected to understand and represent
users in a presentational and a political sense, and to facilitate collaboration that may serve
interests of either operational or managerial stakeholders. The mediator role can be assumed
by different people in both informal and formal positions, such as IS/usability specialists,
researchers, information managers, software implementers, or peers of the user groups (Iivari
et al., 2009; Oostveen & Van den Besselaar, 2004; Titlestad et al., 2009; Gumm et al., 2006;
Barcellini et al., 2008). These positions may have a bearing on the mediators’ forms of
participation, i.e., in terms of extent and degree of participation, and the resulting influence
on the design (Barcellini et al., 2008; Tuovila & Iivari, 2007). For instance, Iivari (2011) state
that, often, HCI specialists’ participation in open source software development projects does
not have any effect on the solutions.

Another strategy that has been adopted in DSD, for enhancing participation, is the use of
workshops that bring together stakeholders groups (Obendorf et al., 2009; D’Andrea et al.,
2008). These workshops are considered important for building the software community
through face-to-face interactions between users (from different contexts or application domain
areas) and developers. The goal is to enable reflections on users’ work in different contexts,
create awareness about requirements of others, and to discuss requirements for future
development (ibid.). In D’Andrea et al. (2008), the workshops also included an aspect of
participants voting, through which priorities of proposed development activities could be
valued. Obendorf et al. (2009) propose to use commented case studies to establish ongoing
communication between users and developers. Commented case studies can be described as
written documentation of use experiences authored by the users, describing the use of
software in different contexts. Design decisions are also documented by the developers in
relation to indicated requirements from the use cases. This makes design decisions more
transparent and enables users to gain insight about the guiding and underlying design
principles.

Furthermore, the design and structure of the software is an important factor in enabling or
hindering participation. It is recommended that the software must support evolution and
emergent structure. This is often achieved through meta-design strategies such as flexible
standards and a modular architecture (D’Andrea et al., 2008; Staring & Titlestad, 2008;
Titlestad et al., 2009).
The PD strategies presented above have been applied in western contexts (Barcellini et al., 2008; D'Andrea et al., 2008; Obendorf et al., 2009; Iivari, 2011) as well as in Developing Country settings (Titlestad et al., 2009; Braa & Sahay, 2013). In the next section, I explore further PD in Developing Countries.

2.3.4 Participatory Design in Developing Countries

The important role of context in influencing the motivations behind PD, and the PD strategies is well recognised (Schuler & Namioka, 1993; Puri et al., 2004). In line with this, Heeks (1999) postulates that there are some contexts in which participation is not a viable technique, e.g. in Developing Countries, due to political or cultural aspects. However, other studies from Developing Countries argue that participation is an important requirement in IS development (Byrne, 2004; Korpela et al., 1998; Mursu, 2002; Puri et al., 2004; Braa, 1996). Still, it is subject to several challenges and therefore requires different PD strategies (ibid.).

One of the identified challenges for user participation is a lack of basic computer skills and limited exposure to IT among users in Developing Countries (Kimaro & Titlestad, 2008). This makes it hard for users to understand the relationship between system design and a running computer application, as well as how they can participate in the mysterious design process (ibid.). Kimaro & Titlestad (2008), therefore, argue for participatory customisation whereby users are introduced to a pre-developed and flexible system, which is then customised, in collaboration with the developers, to meet users’ local needs. This process is perceived as a learning-by-doing process where the users learn about basic computer use and application-specific features, while at the same time customising the system. In this way, users’ suggestions are implemented right away, which keeps the users active and motivated to participate (ibid.). Furthermore, customisation of generic software systems for local use contexts can lead to changes being made to the generic software; thus continuing the participatory design of the system (Gizaw, 2014; Saugene, 2014; Titlestad et al., 2009).

Another challenge for PD relates to monetary or personal motives behind selections of participants, and the lack of motivation by users to participate, which may result in intended users not participating in training and other design activities (Kimaro & Titlestad, 2008). Thus, it is recommended to focus on providing training to “intended users of the system, and not to spend resources on non-users who are not involved in the actual use or maintenance of the system” (Kimaro & Titlestad, 2008, pg.6). On the contrary, other studies advocate for involving multiple stakeholders in HIS development, including the community to be served by the health workers (Braa, 1996; Byrne & Sahay, 2007; Korpela et al., 1998; Puri et al.,
Participation may also extend to stakeholders outside a particular sector (Byrne & Sahay, 2007) and to donors (Saugene, 2014). Puri et al. (2009), therefore, propose that PD should be conceptualized as a process of building participatory networks, which emphasizes the diversity of stakeholders and their participation.

Other organisational challenges to participation, in Developing Countries, have included limited financial and human resources, and lack of commitment of top management (Nhampossa et al., 2004; Kimaro & Titlestad, 2008; Elovaara et al., 2006). For instance, staff shortages in health sectors result in high workloads for health workers, which makes it difficult for them to have time to participate in design processes (Elovaara et al., 2006). Byrne & Sahay (2007), therefore, recommend that in all situations, IS designers need to explore the challenges and opportunities for PD in their particular context.

2.4 Theoretical Perspective: Sociotechnical Approaches in Healthcare

The need for a sociotechnical perspective within Health Informatics has been recognised in existing literature (van Bemmel, 2008; Beuscart-Zéphir et al., 2013). This research draws on studies that have adopted a sociotechnical perspective towards the development of patient care information systems.

In general, sociotechnical approaches aim at increasing understandings of how information systems are developed, introduced, and become part of social practices (Berg et al., 2003). There is no such thing as ‘the’ sociotechnical approach, as the term has several roots (ibid.). The term sociotechnical approach was originally developed by the Tavistock Institute in the UK to emphasise the need to give equal weight to social and technical issues when new work systems were being designed (Mumford, 1987; Mumford, 2000). The focus was therefore to develop systems that were technically efficient and led to high job satisfaction (Avison & Fitzgerald, 2006). This work is part of the early Participatory Design projects (Bjerknes et al., 1987).

The term sociotechnical has also been used in the field of Science and Technology studies (STS), with a focus on the interrelation between the social aspects and the technical aspects, each shaping the other (Berg et al., 2003; Bijker & Law, 1992). The theoretical perspectives are fundamentally concerned with the Social Shaping of Technology; and one of the theoretical approaches within this is Actor-Network Theory (ANT) (Bijker & Law, 1992). Sociotechnical analyses are also part of the field of Computer Supported Cooperative Work,
where the focus is on designing tools for coordination of work between different cooperative actors (Berg et al., 2003; Fitzpatrick & Ellingsen, 2012).

In relation to healthcare, Berg et al. (2003) indicates the common denominators shared by sociotechnical approaches are: a focus on the nature of healthcare work; and the nature of technological innovation. Healthcare work is perceived as a social process that requires health workers to deal with patients’ varying needs and problems; with other healthcare professionals; and with practical contingencies (ibid.). Thus, design is about: finding the synergy between the specific particularities of healthcare work and the informing properties of ICT; and designing interactions from the view of the individuals that work with that technology and the work practices in which it will become embedded (ibid.). However, the technology is not a passive tool but also has its own agency that co-constructs the work activities, and affects the contexts more deeply than is often expected (Berg, 1999b; Berg et al., 2003). Thus, the technology and work practice transform each other, often in unexpected ways (ibid.). Nevertheless, a major challenge for sociotechnical approaches is finding out how to interrelate the nature of healthcare work with the characteristics of formal tools (Berg et al., 2003).

Sociotechnical evaluations are considered to involve researching the way technical and social dimensions change and shape each other over time (Cresswell & Sheikh, 2014). The evaluations encompass investigating how technologies change social processes and how technologies themselves can change over time as a result of their use (ibid.). The dimensions that may be studied include implementation strategies, attitudes and experiences of individuals, organisational consequences, and impact on quality of care (ibid.). There are various theoretical frameworks used in sociotechnical evaluations, such as: the theory of Diffusion of Innovations; Human, Organisation and Technology-fit factors; and Social Shaping of Technology (Cresswell & Sheikh, 2014; Clausen & Yoshinaka, 2004; May et al., 2003; Yusof et al., 2008).

Taking a Social Shaping of Technology perspective, Vikkelsø (2005) proposes an ANT-based understanding of how ICT affects work practices. Vikkelsø (2005) argues that there are three dimensions of medical practice which, in effect of the introduction of the EMR, have been redistributed. These are work tasks, organisational attention and risks. With regards to work tasks and responsibilities, Vikkelsø (2005) indicates that some work tasks may disappear while others emerge. Some of these new tasks are officially recognised whereas others are left
as invisible work. Furthermore, the workload is not equally distributed among staff. In relation to organisational attention, she argues that attention may weaken on some aspects of care and increase the focus on other areas. In terms of risks, Vikkelsø (2005) argues that while EMRs are assumed to reduce notorious risks of errors in patient treatment, they may also introduce other risks for patients, for instance, inconsistent medical information across documents. As such, it may not be obvious that the introduction of EMRs has resulted in work procedures becoming better or more efficient all in all. Rather, it results in a different kind of medical practice with a new distribution of work, responsibilities, capabilities, attention and risks. Hence, the effects of introducing EMRs should be measured in terms of altered work practices, refocused organisational attention and new kinds of risks (ibid.).

Sociotechnical approaches mainly employ qualitative research methods, such as interviews and participant observations, as a way of obtaining empirical knowledge to inform system development or evaluation processes (Berg, 1999a); however, the use of a combination of quantitative and qualitative methods is also recommended for evaluations (Kaplan, 2001; Stoop & Berg, 2003; Cresswell & Sheikh, 2014).

2.4.1 Computer Supported Cooperative Work (CSCW)
The focus in CSCW is placed on understanding the nature and requirements of daily work practices as a starting point for designing any system (Fitzpatrick & Ellingsen, 2012; Schmidt & Bannon, 1992). The emphasis is particularly on understanding the nature and requirements of cooperative work whereby people are mutually dependent in their work (Schmidt & Bannon, 1992). Therefore the observation by Fitzpatrick & Ellingsen (2012) that most CSCW studies primarily focus on the collaboration between different health professionals, especially when looking at healthcare work in hospital and general practice settings, is in line with the goals of the research field. For instance, Ellingsen & Monteiro (2003) highlight how decisions are negotiated among different professional groups based on related but different written accounts of a patient. From their comprehensive review of CSCW studies on healthcare work, Fitzpatrick & Ellingsen (2012) also note that there are few studies that have looked at the collaborative work between health providers and patients in hospital settings, for instance, Mønsted et al. (2011) present how patient’s narrative is an important resource for physicians in making sense of available data in medical records. Otherwise, as highlighted by Piras & Zanutto (2010), patients have essentially been considered to have a passive role as the bearers of symptoms to be treated. It is only recently that the role of patients is being considered in CSCW, primarily facilitated by interests to extend care to the homes to enable, for instance,
self-care and self-monitoring using biomedical technology (Piras & Zanutto, 2010); as well as improved access to and coordination of healthcare through health portals (Winthereik et al., 2008).

There are different design strategies that have been employed at different levels such as the programming, architectural, organisational processes/functional levels aimed at achieving flexibility in the coordination of work (Cabitza & Simone, 2013). Some of these strategies have been presented as software development modelling approaches whilst other strategies are discussed at a more organisational process/functional level. These different strategies have led to different forms of coordination mechanisms. One of the design strategies considered as a flexible type of coordination mechanism is awareness promotion, which allows actors to coordinate their activities on the basis of their consciousness of what the other actors are doing (Cabitza & Simone, 2013; Cabitza et al., 2007). Awareness is defined as the understanding of the activities of others that provides a context for your own activity (ibid.). In this case, coordination can be achieved without an explicit model of the coordinated activities. Thus, in designing IT systems, such as EMR systems, inclusion of awareness promoting functionalities is considered a strategy for coordinating work in a flexible manner (ibid.)

2.4.2 Inscriptions

The concept of inscription originates from Actor-Network Theory (ANT). Basically, ANT considers IS as consisting of actors, both human and nonhumans, which are aligned to form a network (Monteiro, 2001). Thus, the Actor-Network is the network of heterogeneous materials that make up the context (ibid.). ANT provides a set of concepts to describe how, where and to what extent technology/technical artefacts such as standards influence behaviour (ibid.). The concept of inscription refers to the way technical artefacts embody patterns of use and may be used to describe how concrete anticipations and restrictions of future patterns of use are involved in the development and use of a technology (Hanseth & Monteiro, 1997). The work of designers therefore involves inscribing their vision of the world in the technical content of an artefact (Akrich, 1992). In this regard, technologies have even been perceived as inscription devices (Bloomfield, 1991); and it is important to investigate whether the social roles inscribed in the system are at all feasible for the practice where it is implemented (Berg et al., 2003). In addition to the deliberate creation of inscriptions, technologies also possess inherent inscriptions that may change the work practices by introducing new work tasks (Aanestad, 2003). Winthereik et al. (2008) further indicate that inscriptions also exist in the
environment and materials through which a new technology is presented, marketed and distributed.

The strength of an inscription is the degree to which an inscription actually succeeds in enforcing a desired behaviour i.e. whether they must be followed or whether they can be avoided (Hanseth & Monteiro, 1997). This is based on the recognition that inscribed patterns of use may not succeed because the actual use deviates from it (ibid.). This is partly due to how the inscriptions are actually translated in the use setting. Akrich (1992, pg.222) points out that “it is only after the event that we are able to say that objects do this, while human beings do that”. Thus, inscriptions in technology become activated when it is installed in a particular use setting and that is when the strength of the inscription can be determined (Hanseth & Monteiro, 1997; Aanestad, 2003; Winthereik et al., 2008). In essence, technologies may inscribe weak/flexible programs of action while others inscribe strong/inflexible patterns of use (Hanseth & Monteiro, 1997).

This notion of inscription enables analysis of how various kinds of materials attempt to inscribe patterns of use. Braa & Hedberg (2002), for example, used the notion to explain how the District Health Information Software (DHIS) inscribed a decentralized use scenario which clashed with existing centralized organizational structure. In this thesis, the development process is perceived as a process of creating inscriptions and the design principles are perceived to inscribe certain patterns of use. Therefore, the notion of the strength of the inscription is used to point towards the extent to which inscribed patterns of use are realised in the provision of health services.

2.5 Summary and proposed conceptual framework
In this chapter, I have presented an overview of Health Informatics research with the goal of positioning my study within this vast and diverse discipline. This study falls within research about the organisation, application and evaluation of Health Information Systems. My main interest is on patient care information systems used in provision of primary care services. Within this, my central focus is on Electronic Medical Record (EMR) systems. While other literature presents EMRs, Clinical Decision Support Systems, Patient registration systems and Computer-based Provider Order Entry (CPOE) as different types of patient care information systems, I perceive clinical decision support, patient registration, and CPOE as functional components of EMR systems. This is in line with the scope of EMR functionality as presented by Tang & McDonald (2001).
I have also reviewed literature on EMR systems design, which highlights design issues and options important in development of EMR systems as well as recommended design principles. The design issues are related to the format of the data, the data-entry methods, and user interface designs. The literature about design issues and EMR functionality provides a framework for presenting designs and functionality of the EMR systems developed in the present study. The recommended design principles also provide a frame of reference for discussing the designs of the EMR systems in this study. In addition, adopting the concept of *inscriptions* from ANT, I perceive the design options/choices as bearing specific inscribed patterns of use. Thus, in chapter 6, I show inscribed patterns of use within the EMR designs and compare them against the actual use in context. The notion of *strength of the inscription* is used to represent the extent to which inscribed patterns of use are realised in the provision of health services.

Furthermore, I have reviewed literature on EMR systems in Developing Countries, which are of relevance since this study takes place in a Developing Country in Africa. This literature highlights important issues within the context of Developing Countries, which include challenges, recommended designs, and implementation strategies. Among other things, the literature reveals the rising use of Free and Open Source Software (FOSS) in Developing Countries.

Most of the existing studies on EMR systems within health informatics adopt a positivist tradition, focusing on technical designs and quantitative measurement of the effects of EMR systems on healthcare processes and outcomes on patient care. However, other studies indicate that such tradition presents a simplistic view of the relationship between technology and healthcare work, which fails to account for unforeseen consequences. These other studies, thus, advocate for adopting a sociotechnical perspective that considers both technical and social aspects of EMR systems. This sociotechnical perspective is grounded in qualitative research methods, and advocates for developing systems based on in-depth understanding of the work practices and users. Some of the research traditions that adopt a sociotechnical perspective are Participatory Design (PD) and Computer Supported Collaborative Work (CSCW). In this study, I have adopted a sociotechnical perspective on EMR system development, with a focus on Participatory Design.

The literature on PD presented here provides a framework for analysing different forms of participation within this study. More specifically, the literature presents forms of participation
that can take place and the roles of different types of stakeholders. There is, however, limited understanding of how to manage and align different stakeholder interests, and limited studies have characterised their participation and interaction in IS development processes.

Studies of PD in the context of Developing Countries have also been presented, which indicate that participation is contextual and may take different forms in different settings. These studies also reveal challenges of participation in Developing contexts and potential strategies. With the increasing use of FOSS in Developing Countries, which is often developed in a distributed manner, I have also reviewed literature on PD in Distributed Software Development projects. The literature presents challenges for participation and different PD strategies that can be employed.
3 RESEARCH CONTEXT
This chapter presents the context of Malawi. The first section presents the general country profile. In the second section, the socio-economic profile is presented. The health status and concerns in Malawi are presented in the third section. This is followed by a description of the health system in the fourth section. The status of Maternal health services is presented in the fifth section. The Health Information System in Malawi is then presented in the last section.

3.1 Malawi Country Profile
Malawi is a landlocked country in Sub-Saharan Africa covering 118,484 square kilometres of which 20 percent is Lake Malawi. The country shares its borders with Tanzania, Zambia and Mozambique. The country is administratively divided into three regions: Northern, Southern and Central. These regions are further divided into 28 districts countrywide. This study was conducted in two districts in the central region and one district in the southern region.

Malawi is densely populated with a projected population of 15.8 million for the year 2014 and a growth rate of 3.14 percent (NSO, 2008). 51 percent of the population are females and 45 percent are in the childbearing age of 15-49 years (ibid). Overall, 45 percent of the population are aged between 0-14 years, 52 percent are aged between 15-64 years, and 3 percent are over 65 years (The_World_Bank, 2014). The population is predominantly rural, with 85 percent estimated to live in the rural areas (NSO, 2008). There are four major urban centres: Blantyre, Lilongwe, Mzuzu, and Zomba.

Figure 3.1: Map of Malawi and Neighbouring Countries (Msiska, 2009)
3.2 Socio-Economic Profile
Malawi is among the least developed countries in the world, with 50 percent of the population living below the poverty line (NSO, 2012). 57 percent of the rural population is estimated to be living in poverty, while in urban areas, the poverty rate is 17 percent (ibid.).

The literacy rate among the population 15 years and above is 65 percent (NSO, 2012). A lower share of females aged 15 years and above is literate, with a literacy rate of 57 percent; while the male population of the same age group has a literacy rate of 74 percent (ibid.). In addition, a higher proportion of females of this age group (28 percent) have never been to school compared to their male counterparts (14 percent) (ibid.). There is a wide gap between urban and rural areas. In rural areas, 24 percent of the people have never been to school, while in urban areas, only 7 percent of the population (15 years and above) have never been to school. Furthermore, 80 percent of population aged 15 years and above in rural areas do not have any qualification compared to 45 percent in urban areas (ibid.).

The Total Fertility Rate (TFR) for a woman is high in Malawi. It is estimated a woman will bear an average of 5.7 children in her lifetime (NSO & ICF_MACRO, 2011). The TFR is higher for rural women, which is estimated at 6.1 children, whilst the rate is at 4.0 for urban women (ibid.). This implies a higher demand for maternal health services in rural settings than in urban areas.

There is no dominant ethnic group in the country but there is a dominant indigenous language, Chichewa, which shares the status of official language with English. However, all official records in public administration are in English only. Malawi has different tribal, linguistic and cultural groups, and varying customs and religious beliefs. These influence the acceptability of modern practices or ways of life such as education, family planning and modern health care, as opposed to use of traditional health providers (Kanjo, 2012).

Malawi’s electricity supply is limited with only 6 percent electrification rate (Kanjo, 2012). Therefore, access to the electricity grid is limited in rural areas. Only 2 percent of households have electricity in rural areas, while in urban areas, 33 percent of households have electricity (NSO, 2012). In addition, power cuts and fluctuating power levels are a major problem in the country (Douglas, 2009). Furthermore, the road infrastructure in rural areas is poor and motorized transportation is often unavailable (Kanjo, 2012).
3.3 Health Status
The health indicators for Malawi are generally poor. The projected life expectancy at birth, for males and females, was estimated at 48 and 51 respectively (NSO, 2008). There are differences between rural and urban areas, with the life expectancy for females in urban areas estimated at 59, and at 50.9 for those in rural areas.

The Maternal Mortality ratio (MMR) for Malawi has been high over the past years. In 2004, the MMR was measured at 984 maternal deaths per 100,000 live births, and in 2010, it was estimated at 675 deaths per 100,000 live births (NSO & ICF_Macro, 2011). This implies there is need for a steep decline in the ratio for the country to meet the MDG target of 155 by 2015 (Kanjo, 2012). Childhood mortality has also been high in the country. In 2010, the Under-five mortality rate was estimated at 112 deaths per 1,000 live births, and the Infant mortality was at 66 deaths per 1,000 live births (NSO & ICF_Macro, 2011).

The high mortality rates are partly due to the high burden of diseases that Malawi faces. There is high incidence and prevalence of communicable diseases especially malaria, HIV/AIDS and Tuberculosis (NSO & ICF_Macro, 2011; NSO, 2012). The prevalence of non-communicable diseases, such as Cancer, Diabetes and Hypertension, are also increasing. Another major problem in the country is malnutrition.

3.4 The Health System in Malawi
3.4.1 Service providers and Levels of service provision
There are three main agencies providing healthcare services in the country: the Ministry of Health providing 60% of health service, the Christian Health Association of Malawi (CHAM) provides 37% and the Ministry of Local Government provides 1%. In addition, there is a small private-for-profit health sector but this is limited to the urban areas (MoH, 2007). Furthermore, in some of the government health institutions, donors or research-related institutions supplement health service provision.

There are three main levels of service provision within the health system: the primary level comprises of health centres, health posts, dispensaries, and rural hospitals; the secondary level consists of district hospitals and CHAM hospitals; the tertiary level includes four central hospitals and private hospitals with specialist services (MoH, 2007). In recent years, provision of health services at community level (by Health Surveillance Assistants) has been established for some specific health services resulting in four levels of health service delivery.
The health service delivery is focused on the provision of the Essential Health Package (EHP). The EHP consists of a cluster of cost-effective interventions delivered together in order to reduce the total cost of the interventions by reducing the cost to patients obtaining the services as well as the costs of providing services (Mueller et al., 2011). The EHP addresses the major causes of morbidity and mortality among the general population and focuses particularly on medical conditions and service gaps that disproportionately affect the rural poor. Some of the priorities targeted by EHP interventions in Malawi include infectious diseases, adverse maternal and neonatal outcomes, nutritional deficiencies and common injuries (ibid.).

3.4.2 Administrative Organisation

The Ministry of Health (MoH) has overall responsibility for developing, reviewing and enforcing health and related policies for the health sector; developing and reviewing standards, norms and management protocols for service delivery and ensuring that these are communicated to lower level institutions (MoH, 2011). The ministry has several technical departments: Preventive Health, Clinical, Nursing, Health technical support services, Finance and Administration; and Health Services Planning. One of the divisions under Health Service Planning is the Central Monitoring and Evaluation Division (CMED) which is responsible for management of the country’s Health Information Systems and for the oversight of all monitoring and evaluation activities carried out in the health sector in Malawi. CMED works together with the other technical departments to develop data collection tools in form of health passports (for clients), service registers and reporting forms.

Below the central level, the MOH has Zonal Health Support Offices to facilitate the management and coordination of the health services at the operational level. The Zonal Support Office’s functions include technical advice and facilitation support of decentralization, EHP implementation, and inter-district collaboration.

The MOH is further divided into District Health Offices. The office is headed by a District Health Officer who is assisted by a District Health Management Team (DHMT). The team is responsible for the dissemination of national policies, overall coordination of health services and programs, and provision of services at district level. The District Health Office is mainly based at a District Hospital. The DHMT manages and supervises both hospital and peripheral government facilities (i.e. health centres, dispensaries and mobile clinics).
3.4.3 Human Resources

One of the crucial factors affecting the quality of health services is human resources (Mueller et al., 2011). In 2007, the workforce in the health sector was estimated at 33,766 health personnel of which 30 percent were Health Surveillance Assistants; 29 percent were management and support staff, 13 percent nurses, 4 percent technicians, 2 percent medical assistants and 1 percent physicians (Centre-for-Social-Research, 2008). 64 percent of the workforce was employed by the Ministry of Health. The distribution of health personnel between urban and rural areas was uneven, as shown in Table 3.1. The census showed that 62 percent of physicians worked in urban areas, whilst 23 percent were in rural areas. For nurse/midwives, 38 percent worked in urban areas, 33 percent in rural areas and 29 percent in semi-urban areas (ibid.). On the contrary, there are more nurse technicians, medical assistants, HSAs and ward attendants in rural areas compared to urban areas.

Table 3.1: Distribution of staff in the health sector

<table>
<thead>
<tr>
<th>Profession</th>
<th>Location of facility</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
<td>Rural</td>
<td>Semi-urban</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Physician</td>
<td>117</td>
<td>44</td>
<td>29</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>Clinical Officers</td>
<td>250</td>
<td>186</td>
<td>264</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td>Medical Assistants</td>
<td>94</td>
<td>479</td>
<td>134</td>
<td>707</td>
<td></td>
</tr>
<tr>
<td>Nurse/Midwives</td>
<td>1,108</td>
<td>972</td>
<td>852</td>
<td>2,928</td>
<td></td>
</tr>
<tr>
<td>Nurse Technicians</td>
<td>249</td>
<td>383</td>
<td>336</td>
<td>968</td>
<td></td>
</tr>
<tr>
<td>Auxiliary Nurses</td>
<td>131</td>
<td>26</td>
<td>271</td>
<td>428</td>
<td></td>
</tr>
<tr>
<td>HSAs</td>
<td>694</td>
<td>7,967</td>
<td>1,394</td>
<td>10,055</td>
<td></td>
</tr>
<tr>
<td>Ward/Hospital Attendants</td>
<td>1,381</td>
<td>2,760</td>
<td>1,560</td>
<td>5,701</td>
<td></td>
</tr>
</tbody>
</table>

Source: Centre-for-Social-Research (2008)

HSAs receive limited professional training which is given over a period of 10 weeks. The ward attendants are mainly employed as cleaners and therefore do not undergo any professional training. As such, HSAs and Hospital attendants are not considered health professionals (Centre-for-Social-Research, 2008). This implies that the majority of health service providers in rural areas are not health professionals. In terms of their education levels, 48 percent of HSAs have a Junior Certificate of Education (JCE), 46 percent have Malawi Schools Certificate of Education (MSCE), and 3.9 percent have Primary School Leaving Certificate (PSLC). For the ward attendants, the majority (45.8 percent) have JCE, 41.6 percent have a PSLC, and only 11 percent have MSCE.
There is severe shortage of nurses, having a 64% of the 6,084 establishments vacant during the implementation of the fourth National Health Plan (1999-2004). This is because the training outputs are too low to fill the large number of vacant posts. Furthermore, most of the skilled health workers have been leaving the public services mainly due to poor salaries and working conditions. In rural areas, the vacancy rates are high with health facilities having only 1 nurse and some districts do not have any doctor (Centre-for-Social-Research, 2008).

In response, the Malawi Government implemented a Human Resource Programme in 2005, under the Programme of Work (PoW), which aimed at addressing the critical shortage of human resources required to deliver the EHP. The programme activities included financing the recruitment of more health workers to filling the vacant posts, ensuring retention of all trained health workers, and providing in-service training (AHWO, 2009).

In addition to human resources, an important challenge has been limited material resources, including drugs and medical supplies (Mueller et al., 2011). There is persistent insufficient stocks of essential drugs in health facilities, inadequate means of communication and inadequate transport. This has been attributed to the shrinking of the drug budget in the face of the local currency devaluation and increased pilferage of drugs.

### 3.5 Maternal Health Services

The health centres form the majority of health facilities in the country and therefore the most accessible to the rural population. Thus, the health centres are where most women go to seek Maternal health care. At this primary level, basic Maternal and child health services are provided. These services are Antenatal care, delivery (for normal cases), postnatal care, child immunization, and family planning (MoH, 2007; Sharan et al., 2009). The secondary and tertiary level hospitals provide more comprehensive obstetric care, and as such, women observed with obstetric complications at health centres are referred to hospitals (ibid.). However, most women in the rural areas also use traditional medicine and have deliveries in the community using Traditional Birth Attendants (Kanjo, 2012).

As previously mentioned, Maternal Mortality ratio in Malawi remains high, and several factors contributing to this have been identified. An assessment of the quality of Maternal health services in Malawi revealed that poor quality of patient care resulted from negligence by health workers indicating a weak system of accountability, poor compliance with infection prevention practices, inadequate patient monitoring, delays in starting treatment, lack of obstetric life-saving skills knowledge and non-availability of blood supply (Sharan et al.,
Additionally, the study also revealed that delays in seeking care and reaching care from the patients’ side, caused by lack of recognition of danger signs, cultural and financial barrier lead to Maternal deaths.

There are various strategies and activities that have been proposed to address the different challenges faced in the Maternal health system. For improving patient care and management of services, provision of training and supervision, seeking greater accountability from health care providers, and implementing integrated interventions to support the continuum of care have been recommended as strategies (Sharan et al., 2009). Interventions are also needed to address community-level constraints to seeking care and making services more easily affordable and accessible to women.

The Ministry of Health, as part of its road map for accelerating the reduction of Maternal and neonatal mortality in Malawi, devised nine strategies to address the problems in the health system (MoH, 2007). Some of the strategies included strengthening the communication system between health centre and referral hospital, empowering communities to ensure continuum of care, and strengthening monitoring and evaluation mechanisms of Maternal and neonatal services. The efforts reported in this study, were primarily aimed at strengthening the monitoring and evaluation mechanisms of Maternal health services.

3.6 The Health Information System

The Malawi Government, through the Ministry of Health, endorsed a strategic plan aimed at integrating existing information systems into a flexible, accessible, comprehensive Health Management Information System (HMIS) capable of feeding back useful information on a timely basis to those in need of it most (MOHP, 2003). As part of the Ministry’s strategy, District Health Information Software (DHIS) version 1.3 was implemented in Malawi in 2002. DHIS1.3 was a free Microsoft Access based system developed by the Health Information System Program (HISP) in South Africa in conjunction with the University of Oslo in Norway.

DHIS1.3 was implemented at the district level of the health system in Malawi, particularly at the District Health Office to be used by an Assistant Statistician. Thus, in most facilities, the Health Information System was, and still is, paper-based. The health workers record patient data in health passports and registers during the interaction with the patient. At the end of the month and quarter, the data in the registers is aggregated using paper-based reporting forms, which are then sent to the statistician who enters the data into the DHIS (Galimoto, 2007). In
2009, the Ministry of Health commenced a project to upgrade their DHIS from version 1.3 to version 2. DHIS2 is a Free and Open Source Software (FOSS), and its development is coordinated by HISP at the University of Oslo. I have therefore been part of the project in Malawi to upgrade the software to DHIS2.

Apart from this, there have been several efforts to implement Electronic Medical Record Systems in hospitals and health centres in Malawi. The Ministry of Health, through Baobab Health Trust, have implemented Patient registration systems in main central hospitals and in several district hospitals in Malawi. This system has mainly been used for patient registration to capture patients’ demographic data at the hospitals. However, in recent years, an upgraded version of the system has been developed which allows recording of patients’ diagnosis in addition to their demographic data. This system has been piloted in two rural health centres in Lilongwe, for Outpatient Department (OPD) services in those facilities.

In addition to the patient registration systems, Baobab Health Trust has also implemented an EMR system that assists in the delivery of ART services to HIV positive patients in several facilities in Malawi. The system is used to identify patient eligibility, dispense drugs, track patients, and conduct on-going monitoring and evaluation. During the period of this research, Baobab has also developed EMR systems for Maternal Health, and I was involved in these projects. The EMR software solutions developed by Baobab are FOSS applications.

Another EMR system that has been implemented within the Malawi health sector is the Open Medical Records System (OpenMRS). As mentioned in the literature review, OpenMRS is a one of the most widely used FOSS EMR system in Developing Countries, which enables design of customized medical records systems. The Baobab EMR systems presented above are based on the OpenMRS data model. The OpenMRS application itself has been implemented at one District Hospital in Malawi and is used to manage patient and treatment information for the Antiretroviral Treatment (ART) programme.

In the next chapter, I provide more details on my involvement in the HIS projects I have presented in this section.
4 RESEARCH METHODOLOGY
This chapter presents the research process that I went through in my effort to gain knowledge on how Electronic Medical Record systems can be developed for use in rural primary care settings in Malawi. Firstly, the underlying philosophical perspective guiding the research is presented. Following this, the adopted research strategy of Action Research is presented in second section, which provides a detailed description of the AR process in this study. The third section describes the data collection methods used during the AR process. Following this, data analysis approaches employed are presented the fourth section. The ethical considerations made during this study are indicated in the fifth section. The chapter, then, concludes with a reflection on the research methodology.

4.1 Philosophical Perspective
Every research has an underlying philosophical paradigm, which is a set of shared assumptions or ways of thinking about the nature of the world (ontology) and the ways knowledge about it can be acquired (epistemology) (Oates, 2006, pg.282). Two ‘types’ of postulations can be made in relation to the ontology and epistemology of research, “the empirical world can be assumed to be objective and hence independent of humans, or subjective and hence having existence only through the action of humans in creating and recreating it” (Orlikowski & Baroudi, 1991, pg.7).

The assumption that the world is ordered and objective is the perspective of the positivist paradigm, which has been the dominant perspective within Health Informatics and IS research in general (Oates, 2006; Orlikowski & Baroudi, 1991; Greenhalgh et al., 2009). This perspective underlies the scientific method which is concerned with empirical testability of theories to discover unilateral, causal relationships that can predict patterns of behaviour across situations (ibid.). However, as Oates (2006) indicates, this perspective is not suited to studying the social world, i.e. people, organizations, and group structures. This is a limitation to Information Systems research because “the design and use of information technology in organizations in particular is intrinsically embedded in social contexts, marked by time, locale, politics and culture. Neglecting these influences may reveal an incomplete picture of information systems phenomena” (Orlikowski & Baroudi, 1991, pg.12).

The interpretive perspective addresses some of the limitations of positivism as it assumes that the social world is not given, rather it is socially constructed, produced and reinforced by humans through their actions and interactions (Orlikowski & Baroudi, 1991). It therefore
emphasizes the importance of subjective meanings or realities. The epistemological belief is that social process is not captured in hypothetical deductions, covariance and degrees of freedom; instead understanding social process involves getting inside the world of those generating it (ibid.). Oates (2006, pg.292) describes Interpretive IS research as being “concerned with understanding the social context of an IS i.e. the social processes by which it is developed and construed by people and through which it influences and is influenced by its social setting”. Interpretive studies therefore aim to identify, explore and explain how all the factors in a particular setting are related and interdependent as opposed to reductionism used in positivistic research (ibid.). This study therefore adopted an interpretive paradigm as it was considered appropriate for investigating the social process of developing EMR systems for use in rural contexts in Malawi. As the intent of interpretive research is to produce deep insights into information system phenomena in its natural setting (Klein & Myers, 1999; Orlikowski & Baroudi, 1991), this perspective was considered ideal for understanding work practices in delivery of Maternal healthcare, the associated information and communication requirements of health providers and service managers, the information systems development process, and the use and effect of the information systems on the service delivery activities.

A third paradigm within IS research is the critical perspective, which is concerned with critiquing existing social systems, and revealing any contradictions and conflicts in order to overcome oppressive social conditions (Orlikowski & Baroudi, 1991). The critical paradigm is common within the Participatory Design research tradition, especially where user participation is aimed at increasing workplace democracy and empowerment (Bjerknes & Bratteteig, 1995). Although user participation is a focus within this study, I do not perceive this study to belong to the critical research paradigm, as my basis for user participation was not politically motivated. Rather, it was motivated by pragmatic reasons to achieve relevance and usefulness of EMR systems.

4.2 Research Strategy: Action Research
The adopted philosophical perspective for a study is reflected in the research strategy used (Oates, 2006). For the interpretive paradigm, field studies, such as case studies, ethnographies, and action research, are appropriate strategies for generating valid knowledge as these examine people within their social setting (Orlikowski & Baroudi, 1991; Walsham, 2006).
This research adopted action research as the strategy for investigating how EMR systems can be developed to support Maternal health services in rural primary care settings. Action research is grounded in practical action aiming at solving a particular problem whilst simultaneously contributing to knowledge (Baskerville, 1999; Davison et al., 2004). This was particularly appropriate for me as I was interested in practical action towards solving the digital divide between healthcare facilities in rural and urban contexts. The advantages of using action research are that it produces highly relevant research results to practice (Baskerville & Myers, 2004), it enables researcher’s participation in action rather than merely accessing opinions as is the case in interview-only studies (Walsham, 2006), it provides a rewarding experience for researchers who want to work closely with the practitioner community (Baskerville, 1999), and the type of learning represents enhanced understanding of a complex socio-organisational problem (ibid.).

The essence of Action Research (AR) is a simple two-stage process: first, the diagnostic stage involving analysis of the social situation and theory formulation; and second, the therapeutic stage whereby changes are introduced and the effects are studied (Baskerville, 1999). Several forms of AR have been identified in information systems including Canonical AR, Participatory AR, IS prototyping, ETHICS, Soft Systems Methodology, Multiview, and Participant observation (ibid.). However, the dominant/traditional form is the Canonical AR whereby the process is seen to consist of five phases of: 1) Diagnosing; 2) Action planning; 3) Action taking; 4) Evaluating and 5) Specifying learning (Davison et al., 2004; Susman & Evered, 1978). In addition, establishment of a client-system infrastructure in form of researcher-client agreement is considered the guiding foundation for an AR project and should therefore be established before a project is formally initiated (Davison et al., 2004). This study adopted a Canonical AR approach represented in figure 4.1. The activities related to establishment of the client-system infrastructure and to each phase of the AR cycle are explained in the sub-sections that follow.
4.2.1 The Client-System infrastructure

The client system is defined as "the social system in which the members face problems to be solved by action research" (Susman & Evered, 1978, pg.588). The infrastructure within the client system and the action researcher regulate the phases of the AR (ibid.). It is recommended that the client should understand how AR works including its benefits and drawbacks; and the researcher-client agreement should contain mutual guarantees for behaviour in the context of the project (Davison et al., 2004).

In this research, the client was the Ministry of Health in Malawi as the research effort was geared towards improving the Health Information System within the public sector. The details of the research were shared with the ministry, particularly the division responsible for HIS activities, CMED, who then provided their support for the research as it was deemed relevant for the HIS domain. This support was also used as a basis for requesting official approval for the research from the National Health Sciences Research Committee. The research proposal was provided to the committee stipulating the research focus, objectives and data collection methods. The proposal was found to be inadequate for the committee, which led to two rounds of revisions before being accepted. A meeting was held with a member of the research committee whereby concerns and recommendations from the committee were presented and I also clarified some of the issues raised. Thus, through this process of seeking official approval for the research, the resulting action research process was a negotiation between the researcher and the Ministry’s research committee; thereby meeting the criteria for the
Researcher-Client Agreement recommended by Davison et al. (2004). The approval letter is included as appendix 7.

However, in addition to this agreement with the Ministry, the research partnered with a local NGO, Baobab Health Trust, to implement the interventions, which also required getting into an agreement with the organization. A verbal agreement was established during the project initiation with the director of Baobab, which led to me being based at Baobab. However, due to change of management in the organisation, it became clear that although there had been some kind of verbal understanding on working in collaboration on the project, the nature and extent of this collaboration was still unclear to management of Baobab. Thus, not having any supporting documentation led to problems in making progress in the research project. A formal agreement, therefore, had to be developed between Baobab and the University of Oslo to clearly stipulate the scope of the project and scope of work for each party. A Memorandum of Understanding (MoU) was therefore developed between Baobab Health Trust and the University of Oslo during the action planning phase. In this way, it was not only important to have an agreement with the Ministry but also with Baobab due to the collaborative nature of the project. It is therefore important to recognise the existence of other stakeholders that may have to be included in formulating the research-client agreement, or rather the ‘client-system infrastructure’. In addition, although it is recommended that a research-client agreement should be established in the beginning of the project (Davison et al., 2004), this study also shows the emergent nature of the client-system infrastructure during later stages of the AR process as other important stakeholders are identified.

4.2.2 Diagnosing
The goal of the diagnosing phase is to identify the primary problems that are the underlying causes of the organisation’s desire for change (Baskerville, 1999). As such, diagnosing in this study aimed at gaining a deeper understanding of Maternal health services with a focus on identifying HIS-related problems within the Malawian public health sector. This, therefore, involved conducting an analysis of the Maternal healthcare services and the associated information system at all the levels of the health system (i.e. from community to national level). A holistic assessment is recommended in diagnosing (ibid.). Thus, although the primary interest of the research was the facility and community levels in rural settings, other levels were also investigated to obtain a holistic understanding of Maternal health services. This analysis began informally in June 2009 through my involvement in Ministry of Health HIS activities aimed at strengthening the Health Management Information System (HMIS).
These activities included a site visit to a rural health centre, (as part of a health data standards taskforce) where Baobab Health Trust had implemented an Electronic Patient Registration system. During this site visit, I was introduced to the work processes and practices of Maternal healthcare and the related information collection tools in use at a rural health centre. I was also involved in a project that was working to upgrade the HIS software for the Ministry of Health from DHIS1.3 to DHIS2 and through this work, the data collection tools and reporting procedures at district level for various health programs (including Maternal Health) were provided.

Through my involvement in these HIS activities, I discovered that no computer-based systems had been implemented in health facilities to support Maternal health services; however, Baobab Health Trust, was interested in developing and implementing an EMR system to support Maternal healthcare services in the two referral hospitals in Lilongwe. A meeting was therefore held in October 2009, attended by myself, two other researchers in the NUFU project and Baobab’s director. At this meeting, it was revealed that Baobab’s project on Maternal health had not taken off yet as the organisation was still in the process of sourcing funding to support the project. With the interest of my research project being on the use of ICT in rural health centres, the possibilities for collaboration were explored during the meeting and it was foreseen that the Maternal health EMR systems for the hospitals and for the health centre would be similar, the health centre being a smaller version of the hospital system, and therefore the health centre system could work as a resource for the development of the hospital system. Based on this discussion it was later decided, in November 2009, that our research project would work in collaboration with Baobab in the development and implementation of an EMR system for Maternal health.

As part of this collaboration with Baobab, several site visits to the two referral hospitals in Lilongwe were conducted together with Baobab staff to investigate the work flows within the Maternity sections, and thus, identify the system requirements for the proposed system for the hospitals. In addition, meetings were held with hospital staff to discuss the findings from the visits. All of this provided me with an understanding of the delivery of Maternal health services in hospital settings.

Upon gaining ethical clearance for the research from the National Health Sciences Research Committee in Malawi, I conducted a formal and more rigorous situation analysis of the Maternal health services from March to May 2010 in three districts of the country: Lilongwe,
Dowa and Machinga districts. This was done to investigate the health system at district and facility levels. The districts were selected based on various grounds. Lilongwe was chosen, firstly, due to the HIS activities that were already underway as presented above (i.e. the EMR system projects and the DHIS2 project), and secondly, due to its proximity as I was based in the city thereby making the field sites easily accessible. Machinga was chosen on the premises that it was one of the districts where registers for Antenatal care and Maternity were piloted before rolling out throughout the country. Thus, these registers had been in use for more than a year, whilst in other districts the registers had been in use for less than three months. Machinga was therefore appropriate for obtaining feedback on the registers from users who had more experience using the tools. Dowa district was selected based on the fact that it was the closest district where a pilot on Community Based Maternal and Neonatal Health (CBMNH) was taking place. This was of interest to my research as I was also interested in seeing how mobile technologies could be used at community levels to support Maternal health care services.

The number and type of facilities visited varied within the districts, but the essential criteria were that the facilities had to be government-owned, provide Maternal healthcare services, and be physically accessible by car. A total of 19 health facilities were visited during the assessment of Maternal health services from June 2009 till May 2010, the majority being rural health centres. Table 4.1 shows details on the type of facilities visited in each district.

<table>
<thead>
<tr>
<th>District</th>
<th>Health Centre</th>
<th>Rural/community hospital</th>
<th>District hospital</th>
<th>Central hospital</th>
<th>Total facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lilongwe</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Dowa</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Machinga</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total facilities</td>
<td>12</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>19</td>
</tr>
</tbody>
</table>

In addition to the health facilities, I also conducted studies at the District Health Offices of the 3 districts, focusing on understanding management of Maternal health programmes at district level. Furthermore, investigations were done at the zonal level and at the national level,

1The facility is not a district hospital but serves as a referral hospital for obstetric care for the district as well as other districts in the central region.
particularly the Reproductive Health Unit which is in charge of Maternal health programmes in the Ministry of Health. Some of the findings from the situation analysis of Maternal health services are presented in paper 1 and 3 of this thesis.

In addition to assessing Maternal health services, an assessment of the status of integration of EMR systems in Malawi was conducted from October to November 2010, in order to understand the integration strategies/approaches that were employed. This assessment investigated how information was shared within and across hospitals that were known to have implemented EMR systems. The hospitals included Government-owned central hospitals and CHAM hospitals and these were identified through involvement in HIS-related forums such as the National Data Standards workshop/meetings and through collaboration with Baobab. I conducted this assessment with a colleague working at Baobab and the findings from this assessment are presented in paper 2.

Different data collection methods were used during the assessment of Maternal health services and of the integration status, including interviews, document reviews, participant observations and software analysis. The details on the use of these methods in this study are described later in this chapter, in section 4.3.

4.2.3 Action Planning
Immediately after the situation analysis in May 2010, action planning commenced with other researchers involved in the NUFU project, discussing on possible interventions to undertake. As a research team, we decided to work towards implementing EMR systems to support the Maternal healthcare services in rural health centres and community level. The EMRs were seen as a solution mainly for easing data collation and reporting for health workers and improving accessibility/retrieval of patient records during service provision. Ideally, the aim of action planning is to specify actions that should relieve or improve the primary problems and should be done together with practitioners (Baskerville, 1999). In this case, different types of practitioners existed, i.e. the Maternal healthcare workers, their managers, different departments of the Ministry of Health and EMR system providers. These were involved in the action planning process and their involvement is presented in more detail in paper 4. Even though the action planning is supposed to be centred on relieving the primary problems discovered during the diagnosis (ibid.), not all problems could be addressed within this study. Other factors proved to be important in deciding on the interventions to be undertaken, such as the available local competences and research interests.
With the research interest being on rural contexts, the type of hardware and renewable energy solution had to be considered because electricity is lacking or unreliable in the majority of health facilities in Malawi. Therefore, our research team decided to implement the solutions based on the Baobab hardware technologies that had proved to work in rural health centres using renewable sources of energy. In terms of software, Baobab still did not have any EMR system for Maternal healthcare. Rather, Baobab was in the process of developing a Maternity registration system. However, this system was limited in scope merely focusing on patient registration in Maternity wards and did not capture most of the service delivery information. Our team, therefore, decided that there would be need to develop a more comprehensive system that would capture the client data as per the identified requirements. The primary services, which the system would cover, were Antenatal Care, Delivery, and Post-natal Care. However, later on, due to time and financial constraints, it was decided that the research project would only implement a system for Antenatal Care, since it is the starting point of Maternal healthcare. We decided that the EMR system would be developed based on the software development frameworks used by Baobab. This was to ensure that the system could be maintained by Baobab after the research project; and as agreed in the early stages, the system was also supposed to be a resource for development of a hospital system.

Our research team also decided that the system would be implemented in two rural health centres in Lilongwe. The first health centre was a health facility where a Baobab Outpatient module was implemented and was in use. The second health centre was chosen as a representative of a ‘typical’ rural health centre (i.e. having no electricity, limited human resource with no computer skills, poor road infrastructure), nevertheless, recognising that each social setting involves a unique set of interacting human subjects (Baskerville, 1999). Furthermore, with an interest in mobile technology, the research team also decided to customise and implement the DHIS Tracker system in another health centre to experiment the use of a mobile application to support Maternal healthcare services at the community level. DHIS Tracker is a generic free and open source software developed by HISP which, at this time, was primarily aimed at supporting health programmes such as Maternal and child health, even at community level. Our team, therefore, planned to implement the system in one of the health centres in Dowa district where the Community Based Maternal and Neonatal Health services were being piloted (the proposed solution is presented in paper 1). It was also decided that use of the Baobab hardware solution (i.e. Power, network, computing equipment) should be explored to install the DHIS Tracker at the health centre. Thus, the planned actions
for the project were the implementation of the Baobab EMR system in two health centres and the DHIS Tracker system in one health centre.

4.2.4 Action Taking
Action taking is simply described as the implementation of the planned action (Baskerville, 1999). However, in this research, action taking involved undertaking several activities towards the implementation of the planned action, i.e. implementation of the EMR systems. These activities included software development of the Baobab EMR system and customisation of the DHIS Tracker. In addition, parallel to software development and customisation, the required hardware had to be procured and installed at the selected health centres. These activities had their own trajectory with iterations of action taking and evaluation prior to the actual deployment of an operational system at the health centres. However, the requirements for both initiatives were primarily formulated based on the findings from the diagnosis phase. Furthermore, our research team conducted visits to two of the health centres that participated in the situation analysis in order to validate the findings, as shown in Figures 4.2. The feedback provided was input to defining the requirements of the systems.

![Figures 4.2: Researchers and health workers discussing preliminary report](image)

I also conducted visits to the planned implementation sites (i.e. the three health centres) together with Baobab staff. During these visits, the plans to implement the systems were discussed with the local health workers and requirements specific for each health centre were developed. Based on this, a system requirements document for the health centres was developed, which defined the overall system designs, and the hardware and software requirements. Some of the required hardware was procured locally whilst other hardware was procured internationally.
Once the hardware equipment was available, installation was done by Baobab staff from December 2011 to January 2012 for the three health centres. For each facility, a site visit was done after the hardware installation, mainly to test if the power and network systems were functional, as shown in Figures 4.3. The testing team consisted of a Baobab training officer (as a member of the support and deployment team), me, and a technician from the operations team. Some of the problems that were identified during these visits were resolved immediately by the technician.

Figures 4.3a: Technician testing the power system in the server room
Figures 4.3b: Training officer and technician testing power and network ports for workstations
Figures 4.3c: Researcher testing power and network ports for workstations

Figures 4.3: Hardware testing at the health centres

In the subsections that follow, I present the activities performed as part of the action taking process for the different systems, with the Baobab system initiative presented as the first intervention because it was chronologically the first to be implemented; and the DHIS Tracker is presented as the second intervention.

4.2.4.1 First intervention: Baobab EMR system development
Whilst the development of the MOU between Baobab and University of Oslo was underway, Baobab began developing Antenatal EMR software in February 2011. This was part of another project on Prevention of Mother to Child Transmission of HIV (PMTCT), which was funded by the U.S. Center for Disease Control and Prevention (CDC) in Malawi. The development of this system was aimed at deployment at the two referral hospitals in Lilongwe.

Based on specifications for the hospitals (prepared by Baobab), the software was developed and a prototype was made available for internal testing. This internal testing was done mainly
by a Project Coordinator (responsible for the PMTCT project), a Support and Deployment officer and me. Several rounds of testing were done whereby new versions of the prototype were released for testing after the software developer incorporated our feedback. During this development, additional visits to the hospitals were done to get more information on the existing work practices in order to guide the design of the software. After several rounds of internal testing, the system was demonstrated to the HIV/AIDS unit of the Ministry of Health. A demonstration of the system was also done to expected users at one of the hospitals, which was the selected first site of implementation. The system was also later demonstrated to a group of stakeholders from various organisations involved in PMTCT work at the hospital. These included Lighthouse Trust, University of North Carolina (UNC) project and Lilongwe DHO.

Unfortunately, development of the ANC software for the hospitals came to a standstill due to internal circumstances in the organisation. Thus, in order for my research project to move ahead, a software developer was identified to continue working on the ANC software with focus for implementation at target health centres. Software development proceeded with the same process of development and internal testing, however, with minimal involvement of the Baobab staff in the testing. In addition, the target health centres were also visited and the software was demonstrated to the nurses and some of the hospital attendants.

As previously mentioned, the selected first site for implementation was a health centre having a Baobab OPD system. Therefore, it was required to have the ANC software interface with the OPD system, as some of the clients were likely to access both services. Although it had been stated from the beginning that such functionality already existed in Baobab system (and therefore, would not be a problem), we discovered that developing such an interface was going to be challenging because the two systems were based on different versions of the OpenMRS data model. Upgrading these systems to the same version was going to take some time. With time constraints on the research project, a decision was, therefore, made to implement the developed system at the second site, Health Centre A, which did not have any electronic system; hence this issue of integration would not be critical. Furthermore, it was decided that the system would be implemented at the other health centre later on, once an upgraded version, which was being worked on for the hospitals, was available.

Prior to implementation of the system at Health centre A, the software was demonstrated to the Ministry of Health to ensure adherence to the Ministry’s standards. Different departments
of the Ministry were invited to a demonstration together with some of the ministry’s partners who had been involved in the previous demonstrations for the hospital system. Two rounds of demonstrations were done with these stakeholders; with the second demonstration having the nurse from the health centre participating.

A comprehensive assessment of the Antenatal care services in the implementation sites was conducted before the system was implemented due to a long gap between the initial diagnosis and when the systems were ready for implementation. This ‘re-diagnosing’ was conducted from December 2011 to January 2012 in order to assess the situation right before implementation so as to provide a baseline for evaluation. The assessment aimed at collecting measurable dimensions of performance as recommended by Davison et al. (2004), such as time taken during consultations with clients.

Planning for the system deployment was done with Baobab staff and a meeting was also held with the health centre staff to plan for the training and deployment of the system. The training was conducted at the health centre over a period of four days, which I co-facilitated with the training officer from Baobab. The training had 14 participants consisting of the medical assistant (who was the facility in-charge), one nurse, one statistical clerk, three hospital attendants, eight health surveillance assistants and one assistant environmental health officer. The training consisted of ‘theoretical’ sessions involving presentations and discussions, at a general level, on patient records; and practical sessions whereby the devices and system were introduced to the participants and they practiced using them, as shown in Figures 4.4.

The use of the system at the health centre began on 12th March 2012, a day after the training, and I, together with Baobab staff, provided support to the users. Support was provided
throughout the day until the clients were finished. We conducted such support visits the first five days of system use, which stretched over four weeks, due to the schedule of the Antenatal clinics (Antenatal services were provided on Mondays and Thursdays only). After this, I conducted support visits every fortnight.

4.2.4.2 Second intervention: DHIS Tracker customisation and implementation

Analysis of the DHIS Tracker began in July 2010 with customisation of the system based on the findings from the situation analysis. The customisation aimed at configuring the software to support Antenatal, Delivery and Postnatal care services. Thus, the customisation work involved defining these services as health programmes, which included specifying the care processes and data requirements. This work was done continuously over a period of two weeks with a fellow researcher from Mozambique; however, we were unable to finish the customisation during that time due to challenges faced and our limited knowledge of the software. A list of issues identified during the process was compiled to be shared with HISP members involved in the software development in Oslo. In addition, we planned to continue with the customisation, working separately on different tasks as we were based in different countries. However, it proved challenging to progress with the customisation separately and to coordinate the process. Attempts to continue the customisation were made in January 2011 when my colleague from Mozambique visited Malawi, together with a fellow researcher from Malawi. However, during this time, we faced challenges to use our database with the latest version of the DHIS Tracker, and therefore, no progress was made on the customisation. The problem with the database was resolved later when we reached out for help to a fellow researcher in Oslo who was one of the core developers. Still, being located in different countries and with other school commitments, the customisation eventually came to a halt.

Nevertheless, efforts were made to learn more about the DHIS Tracker to progress with the customisation and prepare for implementation. This was done through my participation in a DHIS2 implementers workshop held in Oslo in February 2011 over a period of two weeks. Unfortunately the workshop did not cover much on implementation of the DHIS Tracker. I also participated in a design meeting on DHIS Tracker that was held in Oslo in March 2011. During this meeting, new functionality (developed on the India version) was presented and feedback was provided on what should be implemented in the generic system. Meetings and discussions were also held with colleagues implementing the system in a health centre in Tanzania in an effort to support Maternal health services. Through these discussions, challenges and issues identified in the process were shared.
The efforts to customise DHIS Tracker for Malawi were revived in March 2012, with a focus on supporting Antenatal care services only. The customisation was done with my fellow researcher from Malawi (Figures 4.5a) and it involved designing data entry forms for each Antenatal care visit, with the expectation that the visit data would generate the required monthly cohort report. However, we faced challenges in creating the required cohort report and assistance was sought from other HISP researchers and software developers. Despite the problem with designing the report, the system was demonstrated and tested by expected users at the planned implementation site, Health Centre B, with a focus on testing data entry for the Antenatal care visits, as shown in Figures 4.5b.

Similar to the Baobab system implementation, a comprehensive assessment of the Antenatal services at the health centre was conducted in October 2012 in order to provide baseline data for evaluation. The assessment focused on collecting data on the time taken during consultations with clients, the work flow and work practices.

A meeting was held with the facility in-charge and the nurse to plan the training during which the training dates, time, location, participants and other requirements were identified. The training was conducted over a period of five days (afternoons only) at the health centre with a total of 13 participants. The participants consisted of the medical assistant/facility in-charge, one statistical clerk, three nurses, five hospital attendants, and three Health Surveillance Assistants. The training consisted of ‘theoretical’ sessions where a general introduction to computers, Electronic Medical Records and the DHIS were provided. Other session were practical, whereby the health workers were taught how to use the system and were provided time to practice. Figures 4.6 show some of the training sessions.
Customisation and software installations continued after the training and the system was operational at the health centre on 9th November 2012, one week after the training completed. Support to the users was provided on the first day of use by me, my fellow researcher and a technician from Baobab. The support visits were conducted every day during the first week of using the system and less frequently after that.

4.2.5 Evaluation

In the literature of AR (Baskerville, 1999), evaluation is considered to take place after the actions are completed. Evaluation involves determining whether the theoretical effects of the action were realised, and whether these effects relieved the problems (ibid.). Aside from being an important part of Action Research, evaluation is also crucial to the advancement of the health informatics discipline, as it assists in establishing the role and effects of ICT in the healthcare environment (Nykänen et al., 2011). Evaluation studies attempt to measure the quality as well as the effects of a new ICT on structure, process and outcome of patient care (Ammenwerth et al., 2003). There are two types of evaluations in health informatics research, formative and summative evaluations.

Formative evaluation is performed throughout the systems lifecycle and it provides information for improving the system under development (Nykänen et al., 2011). In this study, formative evaluation was conducted through the continuous assessment of the software during the development and customisation processes, and testing of the hardware installations. Evaluation of the full systems was also done once the systems were operational at the health centres. The systems were assessed in use, i.e. during provision of support to the users and through analysis of the data captured in the systems. This evaluation examined the effect of the system on Antenatal care service delivery in terms of the work flow, the consultation time per client, the completeness and accuracy of the data, wherever possible. Such evaluation led
to problems being identified and these problems were discussed at facility level with the end users as well as the facility in-charge. For the Baobab system implementation, some of the problems also had to be discussed, both at district and national level, in order to find solutions. Thus, meetings were held with Maternal health officers at district and national level. As one of the solutions, a second round of training of the users was conducted, and this was facilitated by a nurse-midwife identified by the Ministry. The training was done in order to explain the medical terminologies because the majority of the end-users did not have medical professional training.

Summative evaluation is focused on assessing the effect or outcome of the evaluation object at a certain point in time after implementation (Nykänen et al., 2011). There are two main approaches to evaluation, the subjectivist/qualitative approach and the objectivist/positivist approach (Wyatt, 1997). The positivist approaches include experiments and randomised controlled clinical trials design (RCT), involve numerical measurement of performance or specific changes in clinical practice against what is most desirable, correct, or positive, i.e. a gold standard (Friedman et al., 2001). On the other hand, qualitative approaches, such as ethnographic studies, use verbal descriptions to illuminate individual and group perspectives on the outcomes of introducing a system (ibid.). In this study, summative evaluations were conducted primarily using qualitative approaches; however, quantitative data on time taken during consultations was also collected. Specifically, the evaluations assessed the Antenatal care services in terms of workflow, consultation time per client, data completeness, accuracy and challenges faced in using the systems. Nevertheless, due to challenges faced in collecting the quantitative data, the findings from the evaluations (presented in paper 6) are primarily on the qualitative data. In Health Centre A, the evaluation was conducted after the Baobab ANC EMR system had been in use for six months i.e. from September to October 2012. In Health Centre B, the evaluation was conducted eight months after deployment of the DHIS Tracker system, from July to August 2013.

4.2.6 Specifying learning
Action research aims to contribute to knowledge on how and why things happen (McNiff & Whitehead, 2011). The explicit specification of learning is indicated as the most critical activity in AR, which can only be achieved through reflection (Davison et al., 2004). Through the formative evaluation of the systems throughout the development processes, reflections were done with the users and other health workers, Baobab staff and other researchers, which resulted in immediate changes in the context as previously presented. In addition, the lessons
from the implementations served as input to the design of the next version of the software (Figure 4.7).

![Figure 4.7: Design meetings at Baobab](image)

Reflection and specification of learning have also taken place through the writing of papers and this thesis. Three types of learning can take place when doing an action research: learning about the context, the theoretical/conceptual framework and the methodology (Checkland & Holwell, 1998). This study contributes to learning about the context of Maternal health services in rural primary care settings by providing insights on the work practices and nature of the healthcare work. It also provides insights on the effects of EMRs on Antenatal care service provision in such settings. In terms of the conceptual framework, the study provides lessons about the appropriateness of EMR design principles and strategies for Maternal health EMR systems in rural primary care settings; as well as lessons on Participatory Design in low resource settings. The findings, discussion and conclusion chapters of this thesis elaborate more on the lessons in relation to the context and conceptual framework. A reflection on the research methodology employed, is presented in section 4.6 of this chapter, which includes lessons on the Action Research strategy. Being an interpretive study, the contributions of this study are in form of rich insights (Walsham, 1995) on the development of Maternal health EMR systems for use in rural settings and implications (Walsham, 1995) for EMR systems’ development processes.

Figure 4.8 summarises the Action Research process of this study. It shows the iterations between the phases of action planning, action taking and evaluation; and the continuous process of learning.
4.2.7 My role as researcher
An action researcher becomes part of the study and therefore has to observe and participate in the phenomena under study (Baskerville, 1999). According to Sykes & Treleaven (2009), an action researcher can assume three types of roles or positions: as insider-researcher, co-researcher or third-person researcher. The insider-researcher engages in first-person action research whereby the researcher describes his/her own experiences, such that views, challenges, reflections and actions of the researcher are brought into the foreground. As a co-researcher, the action researcher relates to participants in a reflective process and views the participants as co-researchers. Third-person action research is directed towards research for the participants, and is more oriented towards action, representing and disseminating knowledge generated by the inquiry.

The role that I had as a researcher can be perceived principally as an insider-researcher, because I was highly involved in the intervention activities. I was based at Baobab Health Trust for three years, from 2009 to 2012, and thus, became a temporary member (Walsham, 1995) of the organisation. During this period, I did most of the activities that were normally done by the various members of Baobab in their projects, thus I had first-hand experience...
with the EMR development process that I write about. Similarly with the DHIS Tracker implementation, I was highly involved in the customisation, training and deployment activities; thereby assuming the role of a customizer/implementer within the HISP network.

More specifically, as the lead researcher in the project, I played a central role throughout the process starting with conducting the situation analysis and producing the preliminary report on the findings. Based on the findings, decision-making concerning interventions was done in consultation with other researchers and the technology providers. I facilitated the implementation of the interventions in the health centres and was responsible for developing the various documents for the process, such as the budgets and work-plans for the interventions, the Memorandum of Understanding, and the system requirements for the health centres. I was also involved in the hardware acquisition process for the health centres by defining the requirements together with the Baobab hardware team and following up on the procurement and installation, and testing of the hardware at the health centres once the hardware was installed.

With regards to the Baobab ANC EMR software development (for the health centres), I was mainly responsible for internal testing of the software as the coding was done by a recruited software developer. I coordinated and facilitated the demonstration and testing sessions of the intermediate versions of the software with the external stakeholders i.e. the end users, Ministry of Health (national and district level) and thus, communicated the feedback from these stakeholders to the developer. I also participated in defining the requirements, testing and demonstrations of other systems for Maternal health for the hospitals which Baobab was working on; however, the Baobab staff coordinated and facilitated the activities for those systems.

In preparation for deployment of the Baobab ANC EMR system, I did the installation and configuration of the server and the workstations to be deployed at the health centre, with assistance from various Baobab staff. I was also responsible for organizing the training and co-facilitated the training which included developing the user manual for the system. Once the system was implemented and in use, I provided onsite support to users during service delivery for the first five days of use and less frequently after that. I also provided support through phone calls. I was therefore responsible for resolving any challenges faced in the process, which included requesting software modifications to the developer, discussing with the Baobab staff, holding meetings with the managers at district and national level, and
organising the additional training for the users. I also conducted the evaluation of the system through an assessment of the ANC service delivery at the health centre after six months of use.

For the DHIS Tracker system, I was involved in customisation of the software, together with two fellow researchers, and this consisted of creating the required health programs, data elements, validation rules and data entry forms. I was involved in the installation and configuration of the workstations and server together with a fellow researcher and with assistance from Baobab staff. In addition, I was responsible for organizing the training; I co-facilitated the training, and co-developed the user manual for the system with my colleague. I also provided onsite support to the users during the first week of using the system during which preliminary evaluation of the system in use was done. After that, support was mainly provided by my colleague and later on a technical assistant was recruited for the Ministry. I conducted the summative evaluation of the system eight months after deployment. The technical assistant recruited for the Ministry also participated in this evaluation by collecting some of the data on my behalf.

Table 4.2 summaries my research activities across the different AR phases and in section 4.6, I reflect further on my role within the AR process.
Table 4.2: Summary of research activities

<table>
<thead>
<tr>
<th>AR Phases</th>
<th>Research Activities</th>
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</thead>
<tbody>
<tr>
<td>Diagnosing</td>
<td>- Conducted interviews and observations at health facilities, district health offices, zonal offices and Ministry of Health&lt;br&gt;- Attended data standards task force meetings, DHIS2- Malawi project meetings, and Baobab Maternity project meetings&lt;br&gt;- Attended training on Antenatal and Maternity registers</td>
</tr>
<tr>
<td>Action Planning</td>
<td>- Conducted meetings/discussions with researchers, and Baobab staff on interventions&lt;br&gt;- Attended DHIS2 implementers training</td>
</tr>
<tr>
<td>Action Taking</td>
<td>- Conducted visits to health facilities to define system requirements&lt;br&gt;- Developed system requirements, budgets, work plans, and MOU&lt;br&gt;- Facilitated procurement and installation of hardware at three health centres&lt;br&gt;- Conducted hardware testing at the health centres</td>
</tr>
<tr>
<td></td>
<td><strong>Baobab EMR development</strong>&lt;br&gt;- Performed software testing continuously&lt;br&gt;- Organized and facilitated software testing with stakeholders in meetings&lt;br&gt;- Conducted interviews and observations at 2 health centres for baseline data collection&lt;br&gt;- Installed and configured server and workstations&lt;br&gt;- Organised and facilitated user training at Health Centre A&lt;br&gt;- Set up system at the health centre and provided support to end-users during first 3 months of use&lt;br&gt;- Conducted observations at the health centre during support visits&lt;br&gt;- Conducted meetings with managers at district and national level&lt;br&gt;- Organised second training at the health centre</td>
</tr>
<tr>
<td></td>
<td><strong>DHIS Tracker development</strong>&lt;br&gt;- Customised the DHIS Tracker for Maternal health programmes (i.e. creating data elements, health programmes, data entry forms and reports)&lt;br&gt;- Attended DHIS training workshops and meetings (local and international)&lt;br&gt;- Organized and facilitated customised software testing with users at Health centre B&lt;br&gt;- Conducted interviews and observations at the health centre to collect baseline data&lt;br&gt;- Installed and configured server and workstations&lt;br&gt;- Organised and facilitated user trainings at the health centre&lt;br&gt;- Set up system at the health centre and provided support to end-users during first week of use&lt;br&gt;- Conducted observations at the health centre during support visits</td>
</tr>
<tr>
<td>Evaluation</td>
<td>- Conducted interviews and observations at the 2 health centres&lt;br&gt;- Conducted meetings with users &amp; facility health staff, managers &amp; officers at district and national level, and Baobab staff.</td>
</tr>
</tbody>
</table>
4.3 Data Collection Methods

Being an interpretive study, this research mainly employed qualitative data collection methods during the different stages of the action research process. The primary methods used were interviews, participant observations and artefact analyses.

4.3.1 Interviews

Interviewing is one of the primary data collection methods in interpretive research as it provides a mechanism for understanding phenomena from the participants’ perspectives (Walsham, 1995). Interviews were conducted during this research, but with varying degrees in the different phases of the action research process. Hand notes were taken during the interviews and in some cases, audio recording was also done.

During the situation analysis on Maternal health services, interviewing was the primary source of data for investigating the work practices and associated Information System (IS). I conducted semi-structured interviews with different professionals working in the health sector including health workers at health facilities and coordinators/managers at district, zonal and national levels of the health system. Interviews, therefore, allowed understanding of the Maternal health services, the IS and associated challenges from the health workers’ and managers’ perspectives. An interview guide was used during the interviews (see appendix 9a), with different questions prepared for different types of professionals. The health workers interviewed were those involved in the provision of different Maternal health services and this included nurse-midwives, doctors, medical assistants, hospital attendants and health surveillance assistants; the majority being nurse-midwives as they were the main providers of Maternal health services. Furthermore, officers from Save the Children and Clinton Health Access Initiative (CHAI) who were involved in Maternal health projects in some of the districts were also interviewed during the diagnosing phase. The number of people interviewed (presented in Table 4.3) was not predefined before the study, but it was rather based on saturation of data collected. I also conducted semi-structured interviews during the investigation on the status of EMR integration. The interviewees were selected based on knowledge of where EMR systems had been implemented and they consisted of hospital IT officers, hospital department supervisors and EMR system developers.

Interviews were also conducted during the action taking phase to obtain clarifications from health workers on the work practices and data requirements. This was done mainly to guide the software development and planning of the implementations. Most of these clarifications were sought from health workers who had been interviewed initially but in some facilities, the
previous informants had relocated or were unavailable resulting in new people being interviewed.

Furthermore, as indicated previously, a re-diagnosing of Antenatal care services was conducted in the three planned implementation sites and semi-structured interviews were also used during this assessment. I interviewed health workers mainly to verify my understanding of the existing work flow in preparation for system deployment as well as to assess the ICT competence of the expected end-users of the system (see interview guide in appendix 9b).

I also conducted semi-structured interviews during the evaluation of the implemented systems at the health facilities (interview guide in appendix 9c). The interviewees were the primary end-users of the system. In addition, ANC clients were also interviewed to get a sense of clients’ perspectives on Antenatal care services with the system in place. The clients interviewed were visiting the facility for subsequent ANC visits; hence they had experienced service delivery with the system in place on previous visits. Another selection criteria was that they had visited the facility before during a previous pregnancy, thus before there was any system in place.

Table 4.3 presents the number of people interviewed during the different phases of the study.

Table 4.3: Number of people interviewed

<table>
<thead>
<tr>
<th>Interviewees</th>
<th>Action Research Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial Diagnosing</td>
</tr>
<tr>
<td></td>
<td>Initial Action Planning</td>
</tr>
<tr>
<td></td>
<td>Action Taking</td>
</tr>
<tr>
<td></td>
<td>Evaluation</td>
</tr>
<tr>
<td>Nurse-midwives</td>
<td>37</td>
</tr>
<tr>
<td>Doctors</td>
<td>1</td>
</tr>
<tr>
<td>Medical Assistants</td>
<td>2</td>
</tr>
<tr>
<td>Hospital Attendants</td>
<td>4</td>
</tr>
<tr>
<td>HSAs</td>
<td>16</td>
</tr>
<tr>
<td>HMIS data clerks</td>
<td>2</td>
</tr>
<tr>
<td>HMIS Statisticians</td>
<td>4</td>
</tr>
<tr>
<td>DNO/SM Coordinators</td>
<td>3</td>
</tr>
<tr>
<td>CHAI &amp; Save the Children staff</td>
<td>4</td>
</tr>
<tr>
<td>MH Zonal technical officer</td>
<td>1</td>
</tr>
<tr>
<td>MH Officers - national level</td>
<td>1</td>
</tr>
<tr>
<td>Hospital IT officers</td>
<td>3</td>
</tr>
<tr>
<td>Hospital department supervisors</td>
<td>3</td>
</tr>
<tr>
<td>ANC Clients</td>
<td></td>
</tr>
<tr>
<td>Total Interviewees</td>
<td>81</td>
</tr>
</tbody>
</table>
Apart from the semi-structured interviews, research data was also collected through informal interviews and discussions with Baobab staff and with officials working in the Ministry of Health particularly in the Central Monitoring and Evaluation Division (CMED) and the HIV/AIDS unit through my involvement in the national DHIS2 project.

4.3.2 Participant Observations

Participant observation is a method in which the researcher takes part in everyday activities related to an area of social life in order to study an aspect of that life through the observation of events in their natural contexts (McKechnie, 2008). In action research, a wide range of data is generated principally through participation (Sykes & Treleaven, 2009). Researchers’ roles can be viewed as ranging from complete observer (no participation), through participant-as-observer (more observer than participant) and observer-as-participant (more participant than observer) to complete participant (McKechnie, 2008).

As presented in the description of my role as a researcher (section 4.2.7), I participated in various activities and thus, collected data through participant observations. In the group activities that I facilitated such as meetings, system demonstrations, and trainings, I assumed the role of observer-as-participant; whilst in other meetings or trainings, I was more of a participant-as-observer. In performing the day-to-day activities, such as internal software testing, customisation, installations/configurations, I was essentially a complete participant.

Furthermore, I conducted observations of the health workers during service delivery to understand the work practices and the use of the HIS data collection tools. Such observations were conducted during the diagnosing of Maternal health services and summative evaluations, with the intent of being a complete observer.

During the initial diagnosing, these observations were used at a minimal level, with observations of provision of services being done in only 5 health facilities. The observation at each facility was done for a day whereby I observed the nurse during provision of Antenatal care, family planning and postnatal check-ups. Other personnel, such as hospital attendants and HSAs, who were assisting in recording in the care registers in some of the facilities, were also observed. I also conducted observations of two staff morning meeting sessions at one of the hospitals in order to understand what kind of reports were required for such meetings and thus, what reports had to be provided by the system. Furthermore, in one of the districts visited, I attended a two-day training on the Antenatal and Maternity registers for health workers from several health facilities (Figure 4.9). The training had 30 participants consisting
of nurse/midwives, hospital/ward attendants and Health Surveillance Assistants. The training came in response to problems observed in data collection and reporting with the registers that had been in use for slightly over a year and therefore it aimed to re-orient the participants on how to fill the registers and aggregate the data for reporting. Through this training, I gained more understanding on data requirements and the various problems/challenges faced by the health workers in collecting this data and in using the registers.

![Figure 4.9: Training on Antenatal and Maternity Registers in Machinga district](image)

I also conducted observations in the assessment of Antenatal care services prior to system implementation in the three selected health facilities. The observations were done with a focus on collecting quantitative data on the time it took to record client data in the health passports and registers during client consultations. Observations were done at each of the facilities over two to four days, spending two to seven hours at the facility per day, depending on the attendance that day. The total number of client consultations observed at each facility ranged from 54 to 89 due to different service attendance.

After implementing the systems, I conducted observations during the first few days of system use when I did support visits. I was at the facility throughout the day i.e. until all Antenatal clients were attended to. A total of nine support visits were made to Health centre A, whilst five support visits were made to Health centre B. During these observations, I mostly assumed the role of an observer-as-participant, whereby I was observing and guiding them on how to use the system and attending to the users’ queries and problems. However, at times, I was also a complete participant whereby I participated in the use of the system at Health Centre A, such as registering clients in the system and in the registers especially when there was limited staff available on those days, as shown in Figure 4.10. This provided insight to some of the
challenges in using the system as well as enabled assessment of the accuracy and completeness of the client data.

Figure 4.10: Recording client's data in the ANC register

During the summative evaluations, I performed observations at the two health centres focusing on collecting time estimates, analysing the workflow and the interaction with the system (Figure 4.11). At each health centre, the observations were done over a period of six days. The observation hours spent per day ranged from two to five hours.

Figure 4.11a: Health worker registering a client in the Baobab ANC EMR system at Health Centre A
Figure 4.11b: Health worker registering clients in the DHIS Tracker at Health Centre B

Figure 4.11: Observations of health workers using the systems

4.3.3 Artefact Analysis

Artefacts can be used as a source of information not available from interview or observational data; and to support or challenge other data sources (Norum, 2008). In this study, I analysed artefacts such as documents and software to collect data for the research. The documents reviewed included training manuals which spelled out the care procedures and associated information requirements. Service registers, health passports and routine reports were also
reviewed to identify health data collected during service provision and the reporting requirements. Blank copies of some of the reports and register pages were provided by the Ministry of Health. During visits at the health facilities, pictures were taken of registers in use at the health facilities, and of reports produced, to document for further analysis on how the data was actually recorded in practice. Blank copies of the woman’s health passport were also obtained from health facilities and pictures of some clients’ health passports were taken for further analysis. Pictures of other documents that were found to be of interest were taken, such as care workflows and guidelines pasted on walls, minutes of facility management meetings and presentations.

Furthermore, I analysed software applications that were in use during the initial diagnosing in an effort to understand the functionality of the applications. The applications analysed were frontline SMS and a Microsoft Access Database for CBMNH. Analysis of software applications was also a central component of the research during the action planning and action taking phase. As presented previously, there was continuous analysis of the functionality and interface designs of the DHIS Tracker and the Baobab (Maternity and Antenatal) systems throughout the process. In addition, OpenMRS was analysed during the planning process as part of exploration of possible software solutions, especially with Baobab systems being based on the OpenMRS data models.

Apart from these, I also analysed the health data captured in the implemented systems and the register books during the evaluations. This was mainly to compare the health data in the system and in the register to evaluate the accuracy and completeness of the health data.

4.4 Data Analysis
A clear distinction between data gathering and data analysis is problematic in qualitative research (Myers, 1997). Thus, in this study, the data analysis commenced during the empirical data collection. During the initial diagnosing, early analysis of data from interviews was done by transcribing the interview notes from the health facilities. Through this process, I revised the interview questions for health workers and grouped them under the themes of: service process flow, patient data capture, availability and use; data storage and access; data aggregation, reporting and local use; referral system; community health activities; other duties/work routines; protocols/guidelines used; and general problems. Furthermore, additional areas for investigation (including health workers to interview) were identified.
After conducting the fieldwork, I compiled the findings from the different health facilities into more general descriptions of the care procedures, data requirements for the different Maternal health services, and problems faced (i.e. general problems and IS-related). Triangulation of data from different sources (Gibson & Brown, 2009) i.e. interview transcripts, documents and observations was done in developing these descriptions of the care activities conducted and the data requirements for each activity. The data requirements consisted of the patient data captured during that activity as well as previously recorded data that was needed for that activity. Further analysis of these findings was then done with a fellow researcher whereby I used these descriptions to discuss the care procedures and we developed process flow diagrams for the following Maternal health services: Antenatal care (Figure 4.12), Delivery, Postnatal care, Post Abortion Care, Family planning and Community Based Maternal and Neonatal health care.

Figure 4.12: Antenatal Care process flow diagram
A preliminary report of the findings was then developed which presented these process flows, data collection and management procedures for each service, the existing challenges related to data collection and management and the data requirements. As previously indicated, this report was discussed with some of the health workers in two health centres, thereby verifying the findings.

During the collection of data for the summative evaluation of the systems at the health centre, a similar approach to data analysis as in the diagnosing was done. In particular, interview notes and observation notes were transcribed for each interview and for each visit respectively. For Health Centre A, I conducted a comparative analysis of the client’s data recorded in the registers and the system off-site, using a copy of the health centre database and pictures of the registers. This involved looking at the data for each client (who was registered in April, 2013) in the EMR and comparing with what was recorded in the registers. However, in Health Centre B, no comparison was made due to known gaps in the usage of the DHIS Tracker that were caused by hardware problems. The findings for each health centre were compiled guided by themes from the interview guide which were: service workflow: system use; effects on ANC delivery and ANC knowledge; data reliability, problems in system use, user support, system disadvantages, other challenges, EMR integration with other data tools, and improvement suggestions. In each health centre, I conducted a meeting with the health centre staff to discuss the findings, hence verifying the data. The preliminary findings were also presented to Baobab staff.

In a broad sense, a sociotechnical design approach was adopted for the development process, hence my focus on obtaining an in-depth understanding of the work procedures and data requirements based on the work practices on the ground. But more specifically, the concept of user participation was of interest to this study, particularly with the aim of understanding participation of users in rural contexts. Thus, different efforts were made to engage users in the development processes, and this has been presented in more detail in paper 4. During the development of the systems, the data mainly consisted of notes from the various activities I participated in, such as project meetings, software testing sessions, trainings and support visits. Field notes were written especially on the trainings and support visits. These field notes were shared with my main supervisor whose feedback included areas for further investigation.

In essence, some of the themes used in this study were identified deductively from literature. For instance, literature on Health Information Systems and EMR systems guided the data
collection exercise, mostly for interviews and service delivery observations; and literature on PD oriented the development process towards user participation. Furthermore, themes from literature reviewed during the process of writing papers and this thesis have also been used to guide the analysis of data. For instance, the dimensions/attributes of participation proposed by Cavaye (1995) have been used to guide analysis of participation in the development processes for the Baobab system and for the DHIS Tracker, in chapter 6. Similarly, the issues discussed on EMR systems in the health informatics literature falling under themes of EMR benefits/effects, functionality, and interface design have been used to discuss, in chapter 6, the design principles and implementation strategies of the two systems in this study and their implications.

At the same time, other themes have emerged inductively mainly during analysis of the data as part of the process of writing papers. For instance, the themes of protocols, work practices and client practices discussed in paper 3 emerged from the data. In particular, based on my reflective analysis of the development process, the initial focus of the paper was to present the challenges that were faced in the design process which were related specifically to designing a system for Maternal health. These challenges included missing dates for client’s Last Menstrual Period, handling of ANC visits conducted in other health facilities, and differences between the defined standard ANC protocol on how to schedule the visits and how the nurse-midwives did it in practice. In engaging in reflective discussions with my supervisors on these challenges, the challenges were seen to revolve mainly around differences between protocols defined at the national level (i.e. both ANC protocols and HIS standards) and the work practices of health workers in the health facilities. Hence, based on this, I revisited my data with these themes in mind, and literature was reviewed on protocols and work practices in EMR systems design. Furthermore, in analysing the emergent design of the EMR system, the design was perceived to reflect weak and strong inscriptions of the protocols; hence, the concept of inscriptions, from Actor-Network Theory (Akrich, 1992), was adopted. Similarly, the concept of stakeholder participation (Avison & Fitzgerald, 2006), discussed in paper 4, evolved from that of user participation due to the emergent involvement of different types of stakeholders in the EMR development process.

Walsham (2006, pg.325) indicates that “the researcher’s best tool for analysis is his or her own mind, supplemented by minds of others when work and ideas are exposed to them”. Thus, engaging in reflective discussions with fellow researchers has been another way of analysing the data collected during this study. For instance, paper 5 is particularly based on reflective analysis of
the challenges we faced in the process of customising and implementing the DHIS Tracker system in two countries, Malawi and Tanzania.

As this thesis consists of two intervention cases in different settings, the analysis of the data has occurred at two levels, within each intervention case and across the cases. In particular, in papers 3 and 4, the analysis was on the development process for the first intervention (the Baobab ANC EMR system); whilst paper 5 analyses the development process for the second intervention (the DHIS Tracker system). In paper 6, a cross-case analysis of the evaluation findings from the two interventions was employed to identify similarities and differences in the effects of the implemented systems on Antenatal care services in the two settings.

Furthermore, in chapter 6, within-case analysis has also been done in discussing the design principles and strategies in relation to the identified effects from the evaluation. Based on these individual case analyses, a cross-case analysis has been employed to identify design principles and strategies that support the use of EMRs for Antenatal care services in rural primary care facilities. This relates to the first research question of this thesis. A cross-case analysis of the participatory design processes from the two intervention cases has also been done in chapter 6 in answering the second research question. This analysis identifies similarities and differences in the nature of user participation (using Cavaye’s dimensions) in the development of the Baobab EMR system (which was a local software development project) and of the DHIS Tracker case (which was a global generic software development project). The analysis further examines the reasons behind the differences and draws implications for Participatory design processes in low resource settings and in Distributed Software Development projects.

### 4.5 Ethical Considerations

During this study, several ethical considerations have been made. For starters, ethical clearance to conduct the study was obtained from the National Health Sciences Research Committee in Malawi (see appendix 7). In addition, permission to conduct the study in the three districts visited was obtained from each District Health Office. Furthermore, permission was sought from the facility in-charge in each health facility visited. At individual level, written consent (consent form in appendix 8) or oral consent was sought from the health workers to conduct interviews, observations, take pictures and access documents.

In writing this thesis, I have aimed to maintain confidentiality and anonymity by not indicating specific names of the health facilities, especially those where the interventions were
implemented. However, as there are not many systems that have been implemented in these settings, it may be possible for some people to identify the facilities involved and associated individuals, for instance, where only one nurse exists.

4.6 Reflections on Research Methodology
In conducting this study, several areas have been challenging. Here, I reflect on these challenges. As noted by Baskerville (1999), one of the problems with action research is that researchers may become too embroiled in the problem setting and lose contact with their obligations to develop general knowledge about related theories. This was one of the challenges I faced as I was at the centre of the activities and was responsible for facilitating interventions. Thus, as much as this provided me with a rich experience of being a practitioner (i.e. a project manager, a designer, customizer, trainer etc.), it also made it challenging for me to switch into the ‘researcher’ mode in the course of the fieldwork and reflect on the process, since most of the time I was dealing with the practical day-to-day activities. This also made it challenging to document some of the spontaneous activities such as design decisions made during informal talks in the corridors at Baobab. In addition, being at the centre of activities also meant that the times when I had to attend to other school engagements elsewhere (e.g. courses, conferences, writing), the progress on the implementation activities suffered. Thus, it was a constant struggle to balance engagement in the practical activities and performing research activities of reflecting, writing and disseminating findings. As a result, a major part of the analysis and writing has occurred after the field work when I have been in Oslo.

Furthermore, conducting research in the real-world settings is known to pose challenges due to the collaborative nature of the research projects. The researcher seldom has complete control over the process (Davison et al., 2004). In my case, the practicalities of obtaining the ethical clearance and of defining the nature of the collaboration and funding involved bureaucratic processes at the different institutions, which was time consuming and affected the progress of the project. The time-consuming aspect of action research has also been highlighted by other researchers (Simonsen, 2009; Walsham, 2006). In my case, due to time constraints as a student, some decisions had to be made for the sake of making progress on my studies; for instance, we implemented systems which did not have fully working reporting functionality, which was very important for the health workers.

In reflecting on the cyclic process model of Canonical Action Research, I have found it challenging to represent the activities according to the cyclic process model due to the
overlaps and iterations in the activities, as shown in the AR process diagram (Figure 4.8). Thus, the process did not involve a sequential unidirectional flow between the phases, but it rather involved going back and forth e.g. between action planning, action taking and evaluation. For instance, the initial plan of implementing a system for Antenatal, delivery and postnatal had to be revised to only Antenatal care. Furthermore, another round of diagnosing had to be conducted prior to deploying the systems to collect baseline data for evaluation. Hence, rather than having several iterations of the full AR process cycle (Davison et al., 2004), iterations between phases occurred within the cycle.

Another challenge that I faced was related to data collection of quantitative data on consultation time during the re-diagnosing and the summative evaluation. Firstly, as much as I tried to act as a complete observer, it was inevitable that I influenced how the services were provided. For instance, my presence in the consultation rooms resulted in the health workers addressing me directly e.g. in form of comments on the client case or in relation to the system (i.e. during evaluation). Secondly, as I conducted most of the data collection on my own (except for the evaluation at Health Centre B), it was challenging to collect quantitative data on health workers’ activities that were occurring concurrently. For instance, at the registration desk, one health worker would be weighing the clients whilst another did the recording of the weight in the health passports. Thus, most of the data collected during the re-diagnosing was from observations in the nurses’ consultation room. Due to the changes in the work practices following the introduction of the systems (which included shifting some tasks to other health workers) a direct comparative analysis of the consultation times before and after the system implementations has been challenging as the work of the nurse was distributed among different health workers. Thus, collection of quantitative data required more researchers or research assistants with clearly defined standards of what to observe.

Furthermore, in reflecting on the service observations I conducted, it is likely that I influenced how they actually performed their work. For instance, although I introduced myself to them as a mere student conducting research, some of the health workers introduced me to clients as their ‘senior from town’, probably because of my job in the Malawi Government. Hence, they probably viewed my visits as supervisory visits which could have affected their work performance. For instance, one health worker indicated it was good that I visited them because she was of the view that they worked differently when I was there. In addition, the fact that I conducted the implementation of the systems and also did the evaluations, there is possibility that some of the health workers were not able to openly give negative feedback on
the system implementations. Thus, some of the challenges and problems identified have been through my observations of the systems in use, which is also subject to my own bias. However, having meetings with the health workers on the findings has contributed in validating the data from the different data collection methods employed.

Lastly, I have conducted a first-person action research which involves self-reporting; and as indicated by Walsham (1995, pg.78), “Self-reporting faces the twin dangers of over-modesty and self-aggrandisement, and it is particularly difficult to steer a middle path between these two extremes”. Thus, this thesis is probably a victim of this.
5 RESEARCH FINDINGS

This chapter presents the findings of this research, which consist of six papers. The first section provides a summary of the main findings in the individual papers. The second section summaries how each paper relates to the research questions.

5.1 Summary of Papers

Paper 1: Use of mobile technology to support provision of community-based Maternal and neonatal care in Developing Countries

This paper draws on data collected during the initial diagnosing of the Action research project, which was conducted in 2010. It presents findings on Maternal health service delivery at community level. There are different types of community health workers, who are described in the paper; however, the primary focus is on the work of Health Surveillance Assistants (HSAs), who serve as the main link between the communities and the health facilities.

The paper describes the work activities that the HSAs performed at community level in relation to Maternal and neonatal care. The findings revealed that the involvement of HSAs in Maternal health services was a relatively new phenomenon in the healthcare system and as such, it varied across the districts. In some districts, this involvement was undertaken as part of a pilot project on Community Based Maternal and Neonatal care (CBMNC), whilst in other places, their involvement was part of a programme on Prevention of Mother to Child Transmission of HIV (PMTCT).

In summary, the work activities of the HSAs included: conducting follow-up on Antenatal clients who had missed ANC appointments; conducting scheduled household visits to pregnant women; collecting data on Antenatal services and deliveries per household using village health registers; and providing Maternal health education and counselling through community sensitisation campaigns.

Based on the analysis of these work activities and literature investigation of mobile-health (mhealth) applications being used in Developing Countries, the paper proposes how mhealth applications, coupled with implementation of Electronic Health Records, could be used to support the work of HSAs. It describes the proposed architectural design of such a system. In this regard, the paper presents the overall ICT-based solution that was envisioned in this
study, which aimed at supporting Maternal health services at both, health facility and community level.

**Paper 2: A scrutiny of the integration status and standardization process of Electronic Medical Record Systems in Malawi**  

This paper focuses on the issue of integration of EMR systems, which is central in the development of EMR systems. The paper provides an overview of Patient Care information systems implemented in health facilities in Malawi, and the level of integration between those systems. The paper reflects the status of implemented systems and level of integration as of November 2010.

The findings revealed that most implementations of electronic information systems were donor-funded and research-driven. Since the interest of most donors and research were on HIV/AIDS, most of the EMR systems were geared towards this area. There were, however, other systems implemented for Diabetes, Outpatient care, and Inpatient care. Systems had also been implemented for other hospital departments including Radiology, Laboratory, and Pharmacy. The systems developed by Baobab Health Trust were the most widely scaled in terms of the number of implementation sites.

In terms of the level of integration between the electronic systems, the study revealed that there was limited exchange of data electronically between the systems. Rather the data was exchanged between different service providers mostly through printouts from the systems. Nevertheless, there was exchange of some data electronically between different types of systems that were developed by the same organisation.

Several efforts were underway to facilitate electronic exchange of data between the existing systems. These efforts were both, at organisational level and national level. Some of the implementers had partnered to work towards developing modules for exchanging patient data between their systems. At national level, a data standards taskforce had been established to facilitate the development of required standards. One of the initiatives was the development of a national patient identification system. Baobab Health Trust was leading the development of this system which was based on its existing patient ID system. In addition, DHIS 2 was being piloted to serve as the data warehouse that would integrate data from different electronic and paper-based systems within the health sector at national level.
The paper analyses the different dimensions of integration required within the context and provides recommendations on how to progress with the integration efforts.

**Paper 3: Balancing Work Practices and Protocols in the design of EMR systems. The case of developing an EMR system for Antenatal Care services in Malawi**


This paper presents the research findings with regards to the process of developing the Baobab EMR system for Antenatal Care (ANC) services. It draws on data collected throughout the different phases of the Action research project. It presents findings on Antenatal care work practices and the associated paper-based health information system that was in use prior to implementing EMR systems. It also presents findings on the ANC protocol defined at the national level that was meant to guide the delivery of services in practice.

The paper highlights discrepancies between the protocols and the work practices that became apparent in the course of developing the Baobab ANC EMR system. These discrepancies were due to several factors including high workloads caused by staff shortages, lack of medical supplies and equipment, misunderstanding of the protocol by the health workers, and client care seeking practices. The paper also presents how these discrepancies were addressed in the EMR design.

The analysis reveals that in dealing with these discrepancies, some of the designs were geared towards the work practices whilst others were more in line with the protocol. Nevertheless, despite the designs being more in line with the work practices, the protocols were still inscribed in form of weak inscriptions. These were aimed at creating awareness of the recommended course of action according to the protocol, without actually enforcing adherence to the protocol. However, in other cases where the design was geared towards the protocol, strong inscriptions of the protocol were created, aiming at preventing deviations from the protocol.

By examining the discrepancies and the emergent design of the EMR system, the findings show that clients play a central informative role in healthcare that influences whether health workers are able to provide care according to protocol or not. As such, in defining the data requirements, considerations had to be made on the clients’ ability to provide the required information, which in turn influenced the emergent EMR design. The paper therefore argues
for perceiving the clients as cooperative actors in healthcare work and hence, the need to consider their roles and practices when developing EMR system.

Paper 4:  **Stakeholder Participation in the development of an Electronic Medical Record system in Malawi**

Marlen Stacey Chawani, Jens Kaasbøll, and Sisse Finken. Accepted for Participatory Design Conference, 2014.

The paper presents a participatory design perspective on the development process of the Baobab ANC EMR system. It examines the roles and forms of participation of different stakeholders involved during the process. The stakeholders fell within the groups of users, managers, technology providers, health service partners, donors and clients/patients.

The form of participation for each stakeholder group are described along the dimensions proposed by Cavaye (1995), which are type, extent, content, degree and influence. An important finding from the analysis was that the composition of the end user group transformed during the process. Initially, the expected end-users consisted of nurse-midwives and Maternity hospital attendants who were involved in Maternal health services at the facilities, however, in the latter phases, other health workers at the facilities were identified as end users. Furthermore, the degree of participation of the end users varied at different stages (i.e. the extent) with the participation being informative and consultative in the early stages, but became more decisive as the development progressed. The end users influenced both social and technical aspects of the system which included the software and hardware design, security requirements, and the work practice.

The findings also revealed challenges in participation with regards to users located in rural contexts. Some of the users could not effectively participate due to limited understanding of the data requirements that were defined at national level. Furthermore, due to incorporation of other health workers who were not previously involved in Maternal health work, these could not effectively participate on data requirements. In this regard, involving other stakeholders such as managers and other health experts supplemented this lack of knowledge among the expected end users. The paper, therefore, argues for the need to leave participation open for contributions of various stakeholders. With the involvement of multiple stakeholders, designers assume a mediator role as they have to negotiate between different stakeholders.
Challenges of Mediation in Global Software Development: Strategies for enhancing Participation.


The paper reports on the development process of the DHIS Tracker at global level and its customisation and implementation for use to support Maternal health care services in Malawi and Tanzania. In Malawi, the customisation and implementation was conducted by the first two authors, while the third author was responsible for the customisation and implementation in Tanzania. The paper presents a reflective account of our participation, as researcher-designers, in the software development process at a global level. We assumed the role of mediators which involved customising the generic DHIS Tracker to fit the local requirements, as well as, communicating local requirements to the global team of software developers.

The paper highlights challenges of user participation through mediators, in a globally Distributed Software Development project. These challenges were related to the geographical distribution of mediators and developers, which resulted in problems with the flow of information. In particular, as mediators, we faced challenges to communicate local requirements to the developers, and to obtain information and assistance from the developers. We also faced challenges caused by the distribution of roles within the project which resulted in a hierarchal organisation of the project. Due to this setup, incorporation of local requirements within the global generic software required approval and authorisation by coordinators. Thus, although we participated in workshops and other meetings and presented the local requirements, we had limited influence on the outcome of the software. This had implications on the progress of the projects and led to the deployment of a customised DHIS Tracker with missing functionality for generating reports, which was frustrating for users.

Based on the analysis of these challenges, several strategies are proposed for enhancing participation in global software development projects. One of these strategies is to afford mediators voting rights to determine relevance and criticality of proposed functionality. In addition, recognising that it is not always possible for relevant stakeholders to participate in workshops or in the decision-making, transparency on the rationale behind the choices made is important. Thus, enhancing transparency through increased documentation on the decision-making process is argued for. Furthermore, the need for a more flexible software architecture that provides room for more local software development is emphasised.
Paper 6: A cross-case analysis of the effects of EMR deployment on Antenatal Care Services in Rural Health Centres in Malawi

Marlen Stacey Chawani. Submitted to Journal of Health Informatics in Africa

This paper presents the design principles and technical designs of the two systems and the contexts in which they were implemented. It further describes how the systems were used and the perceived effects from the perspective of the users and the ANC clients. The perceived effects are based on evaluation studies undertaken six months after deployment in the Baobab case, and after eight months in the DHIS Tracker case.

The Baobab ANC EMR system\(^2\) was based on the underlying principle of a Point-of-Care (PoC) EMR system. The overall objective was to support Antenatal care services by capturing all the client data recorded in the health passport and registers in order to be able to produce monthly reports. The functionality of the system consisted of patient registration and issuing of patient IDs; capturing and validating ANC visit data; printing of patient IDs and visit summaries; providing decision support on the care process through e.g. alerts and reminders; reviewing the captured data; and providing statistical reports. The patient IDs were printed as a barcode that was stuck on the clients’ health passports. The client’s record could be retrieved in the EMR by scanning the barcode using a barcode reader, or searching using the name.

With the PoC approach, the use of a touchscreen clinical workstation at each point of care was adopted. For the interface design, a wizard-like approach to data entry was used with grouping and sequencing of related data elements. The sequencing allowed branching of data elements based on the data values that were entered. Validation checks were also included for error prevention during data entry. The use of menu selection was employed wherever possible and use of free text data entry was limited to data elements where all the possible values/responses could not be exhausted.

The evaluation of the Baobab ANC EMR implementation revealed that the end-users perceived the effects of introducing the EMR on Antenatal care services as: reduce workload on the nurse; faster service delivery; increased knowledge of Antenatal care; improved storage of data, and improved data accuracy.

\(^2\) Presented as ABC EMR system in the appended paper
In terms of the DHIS Tracker system\(^3\), the system was guided by the overall principle of being a basic transactional system, for managing and analysing transactional data. The functionality of the DHIS Tracker system consisted of registration of the clients/patients with a possibility for specifying different types of IDs such as national patient IDs or service registration numbers. Therefore to retrieve a patient record, different criteria could be used for searching including the name and identifiers. The customised system had functionality for enrolling the client to an ANC program. Once enrolment was successful, ANC visits for the client were scheduled based on the predefined ANC protocol. However the visit dates could be changed if needed. The system provided indication on the status of the visits, e.g. whether the visit had occurred or was overdue. As presented in paper 5, functionality for generating monthly reports was not configured in the implemented software.

The data for each visit could be captured using a predefined form for that visit. The forms were designed to allow for a full preview of data entered on previous visits. Validation checks were also included for error prevention during data entry. Completeness checks for the forms were also incorporated for each form. Drop down lists were used for data elements with predefined options, with a few data elements being able to enter free text. Other data elements were in numeric form.

The effects of introducing the DHIS Tracker system were perceived as: delays in the provision of ANC services; increased workload; increased knowledge of Antenatal care; and improved data storage.

The analysis of the findings revealed that introducing EMRs in the provision of Antenatal care services in the two rural health centres had the effects of: redistributing work and increasing collaboration among different types of health workers; increasing the attention and knowledge of health workers on the health domain; and redistributing the risks in the care and data quality.

### 5.2 Synthesis of the findings

Table 5.1 summarises how the papers contribute towards answering the research questions. A detailed discussion of the findings in relation to the research questions is presented in the next chapter.

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\(^3\) Presented as XYZ EMR system in the appended paper.
### Table 5.1: Summary of research papers

<table>
<thead>
<tr>
<th>Research Paper</th>
<th>Research questions</th>
<th>What design principles and strategies support the use of EMR systems in the provision of Maternal health services in rural primary care settings?</th>
<th>What is the nature of user participation in the development of Maternal health EMR systems for use in rural primary care settings?</th>
</tr>
</thead>
</table>
| Paper 1        | - The paper describes the Maternal health services provided in rural settings at community level by HSAs.  
- It identifies the information and communication requirements in their work.  
- It presents the potential use of an EHR/mhealth application to address their needs and the proposed overall design of the solution. | - It presents the involvement of HSAs in Maternal and Child health service provision at community level | |
| Paper 2        | - The paper deals with the design issue of integration.  
- It identifies the level of EMR integration in the health sector.  
- It identifies standards being developed at national level. | - It highlights the role of donors and researchers as most EMR system implementations are donor-funded and research-driven. | |
| Paper 3        | - It describes Antenatal Care work practices. It presents the ANC protocol that is supposed to guide the work practices.  
- It identifies factors that affect provision of ANC services according to the defined protocol.  
- It presents the design principles & strategies for the Baobab ANC EMR system  
- It proposes the design strategy of creating weak and strong inscriptions of the protocols. | - It presents how the user’s work practices were addressed in design decisions made during the development process.  
- It presents the difficulty to design EMR systems based on users’ work practices only.  
- It highlights the role of clients in Maternal healthcare work. | |
| Paper 4        | N/A                | - It presents the forms of user participation and of other stakeholders in the development of the Baobab ANC EMR system.  
- It presents challenges in user participation | |
| Paper 5        | N/A                | - It presents challenges of user participation, through mediators, in the development of the DHIS Tracker system. | |
| Paper 6        | - It presents the designs of the two systems and the implementation contexts (i.e. the health centres)  
- It presents how the systems were used in Antenatal care service delivery at the health centres.  
- It presents the perceived effects of the systems on Antenatal care services.  
- It presents the challenges faced in using the systems in those settings. | - It presents the outcome of the participation in terms of the system designs and use in the implemented health centres. |
6 DISCUSSION & IMPLICATIONS

This chapter discusses the research findings presented in the previous chapter. The first section discusses the development of EMR systems for rural primary care settings with a focus on EMR design principles and strategies. The second section discusses the Participatory Design aspect of the development process.

6.1 EMR Design principles and strategies

The first research question guiding this study is:

\[ RQ1: \text{What design principles and strategies support the use of EMR systems in the provision of Maternal health services in rural primary care settings in Malawi?} \]

To answer this question, I discuss the design principles and strategies for the EMRs that were implemented in this research and the effects of the systems on Antenatal care services.

Papers 3 and 6 of this thesis present the design principles of the two EMR systems implemented in this study. Some of these principles have been highlighted in previous studies, as presented in the literature review chapter (section 2.2). The use of the EMRs and the perceived effects on Antenatal care services have also been presented in paper 6. There are differences and similarities in the designs of the two systems. In addition, the use contexts were also different in terms of how the services were organised, the staffing levels and even the personal attributes of the healthcare providers, among other things. Thus, the primary aim is to understand how these design principles affected Antenatal care work within that sociotechnical configuration of health services. I, therefore, discuss the design principles in relation to the observed use, the effects and challenges faced for each implementation case separately. Following this, I draw on the two cases to present the implications for design of Antenatal care EMRs systems for rural primary care health facilities.

6.1.1 The Baobab ANC EMR system

6.1.1.1 The Point of Care Approach

The Baobab ANC EMR system was guided by the overall principle of a Point-of-Care (PoC) EMR system that supports the clinical care process. Associated with this PoC approach was the specific design to have a touchscreen clinical workstation at each point of care. This inscribed a real-time pattern of use, and thus, a maximum level of use. The use of EMRs at the point of care is the most challenging form of data entry, but is the ultimate goal/ideal that implementers and policy makers are striving for (Tang & McDonald, 2001; Car et al., 2008; WHO, 2012). In developing such an EMR, defining the workflow of the Antenatal care
process was an important part of the development process. The analysis of the workflow revealed a process flow which involved provision of services such as HIV testing and TTV immunisation but these were considered outside the scope of the research project. As such, though according to the design principle, each point of care should’ve had a workstation, the architectural design of the EMR system did not include workstations specifically for HIV testing and TTV provision. Rather, workstations were provided for three points of care: a registration desk; an ANC examination room; and a history-taking room (due to shifting of the history-taking task from the nurse to the other health workers).

Although a linear workflow had been defined for the ANC care process during the deployment, the evaluation findings revealed that the activities occurred rather concurrently. For instance, one health worker would be doing the registration of clients in the EMR, while another was taking their weights and heights, and sometimes the nurse would be taking their BPs simultaneously. Thus, although the inscribed pattern of use for a PoC system was immediate data entry as the work task was being done, for some of the activities such as weighing, the health workers would write down the values first (either in the health passport or on a piece of paper) and then enter the data in the EMR later on. In addition, since a workstation was not provided in the HIV testing room, the entry of the HIV test result was expected to be somehow retrospective (captured by the nurse). Thus, it was challenging to have a complete PoC EMR system with real-time data entry due to the concurrent activities being done and the limited number of workstations.

As presented in paper 6, one of the unforeseen effects of implementing the EMR system was increased collaboration with other types of health workers in the provision of Antenatal care services, particularly HSAs, statistical clerk and hospital attendants from the Outpatient Department (OPD). This inevitably resulted in the need for more coordination between the health workers especially as their work activities were occurring concurrently. Incorporating inscriptions that enforce a strict adherence to the proposed linear workflow is one way that EMR could support coordination of the Antenatal care work. However, previous studies have shown that the nature of healthcare is ambiguous and non-linear (Ash et al., 2004); as such trying to enforce a strict linear workflow in healthcare settings is often challenging. Alternatively, other studies from CSCW advocate for EMR designs that create awareness on the status of the care work (Cabitza et al., 2007). In the Baobab ANC EMR, the statistical summary on the dashboard provided such awareness to the health workers on the progress of work at the different points of care. For instance, the health workers could see how many
clients had been registered and how many were yet to be seen by the nurse. In addition, if the number of clients registered and those examined didn’t balance up at the end of the day, it prompted discussion among the health workers as to what had happened for this discrepancy. Furthermore, the patient dashboard also had colour codes used on the tabs to indicate whether data was entered or not, which was aimed to create awareness on the work tasks that had already been done and what data was still missing. Nevertheless, analysis of the effects reveal that these designs did not fully support the coordination required between the health workers as gaps were evident in some of the data elements. Thus, EMR designs need to incorporate functionality that supports coordination of the work.

6.1.1.2 The functionality
The functionality of the EMR included patient/client registration and issuing of patient IDs that were printed as a barcode that was stuck on the health passport. In addition, it also included functionality for printing the visit data to eliminate the need to write in the health passport. However, as presented previously, writing was not completely eliminated. Nevertheless, the ability to print the visit summary was considered as one of the useful features for some of the health workers as it reduced the need for writing (which was perceived to be tiring). Furthermore, the printing of the barcode was also considered as an important feature for the health workers, for instance, one health worker indicated that the barcode was an indication that the woman came to the facility. In this regard, the EMR system was integrated with the existing paper-based IS. Although implementers acknowledge the need for running the EMR system in parallel to the paper-based system during a ‘transition/phase in period’ (Castelnuovo et al., 2012), the integration of the EMR and paper-based system is often not incorporated in EMR designs. Instead, EMR systems are often designed with the perspective that they will replace paper-based systems and focus is on integration with other electronic information systems (Blaya et al., 2010). For instance, as presented in paper 2, the need for integration of different electronic systems is well recognised in the Malawian context with various efforts being implemented. However, at an operational level, integration with existing paper-based information systems from the very beginning is a crucial part of integrating the EMRs into the healthcare work practice.

Furthermore, as presented in paper 3, the EMR system design also incorporated functionality for decision support that would facilitate adherence to the care protocol. These were incorporated in form of: alerts and reminders on, e.g., required tests; colour coding on the tabs and data elements to indicate when there was a high risk factor; scheduling of visits.
based on the FANC gestation weeks; and mandatory data elements e.g. LMP and the detailed obstetric history. Some of these were weak inscriptions of the protocols that were aimed at serving a purpose of promoting awareness of the recommended course of action, whilst others were strong inscriptions aimed at enforcing adherence to the protocol. The recommendation that applications should allow providers to override a system suggestion (Tang & McDonald, 2001) can be viewed as a call for the implementation of weak inscriptions in the design of EMRs.

Bearing in mind that some of the weak inscriptions of the protocol were implemented to accommodate deviations due to contextual contingencies, the evaluation did not specifically assess the effect of the ‘intended’ weak inscriptions. However, for the inscription on scheduling of the visits, this was aimed to be a strong inscription; but, due to an oversight on implementing the restrictions, it ended up being a weak inscription as visits were still scheduled outside the intended range for gestation. At the same time, implementing the restrictions may also have caused challenges to the care process since the LMP, on which the scheduling was based on, was not always accurate. Nevertheless, the mandatory data elements were strong inscriptions of the protocol as the health workers were forced to collect this information. Thus, while gaps were common on some of the data elements with the paper-based system (for instance the LMP date), with the EMR, this could not be left unspecified, thereby enforcing adherence to the protocol. Car et al. (2008) indicate the benefits of EMRs are partly dependent on the extent to which decision support is integrated. This extent can be perceived as the strength of the inscriptions that are incorporated in relation to decision support.

The literature also indicates that an EMR system should incorporate functionality for communication between different health providers as well as clients (Tang & McDonald, 2001). In the Baobab ANC system, no electronic communication functionality was provided for communicating with, for instance, other health facilities. Thus, the EMR visit summaries were also meant for communication with health workers in other facilities. Communication is also an important part in cooperative work (Andersen et al., 2002), and the clients being an important actor in the performance of care work, communication between health workers and the clients is of importance. Regrettably, such functionality was not incorporated in the EMR design, including the design of the printouts for the health passport. However, it is important for future work to explore, for instance, how the EMR interface can be designed to enhance communication between the health provider and client during consultations.
6.1.1.3 **The Interface design**

As indicated in paper 3 and 6, a touchscreen interface with a wizard-like approach to data entry was adopted whereby data elements for a form were presented as a sequence of screens. Each screen was limited to the collection of one data element and this can be seen to be in line with the recommendation by Guest & Conrick (2006), of reducing the overall information density on a screen. In turn, this inscribed the collection of data in a specific sequence, which can be perceived to be in conflict with ensuring *user control* (Ginneken et al., 1997).

Grouping of data elements was also an important part of the design, and this was guided by the ANC work/process flow. The sequencing allowed branching of data elements based on the data values for related elements. For instance, if it was the first pregnancy for a client i.e. Gravida 1, then there was no need to collect data about the obstetric history. Incorporation of such logic between data elements has been perceived as a way of reducing errors as well as a time-saving measure in other cases (Douglas et al., 2010; Waters et al., 2010). In this case, time savings were not specifically attributed to this feature; however the users perceived the EMR system to be generally faster than writing. Some of the users also perceived the data in the EMR to be accurate due to the incorporation of validation checks on consistency between the data elements e.g. Gravida, Parity and abortions; as well as range checks for individual data elements. Yet, at the same time, how the obstetric history data elements were sequenced also posed challenges to the history-taking process because of language and cultural aspects related to the clients, as described in paper 6. Thus, the inscribed logical sequence of the data elements did not fully address the client-related aspects of the care process. Further to this, the process for correcting data, which required re-entering all the obstetric history, made it challenging for the users to correct the data in the EMR system. This led to inaccuracies in the data. This exemplifies how local contextual factors relating to clients, such as culture and language, can influence the care process and the accuracy of the data. Hence, while sequencing of data elements and validations are expected to have a positive effect on data accuracy (Tang & McDonald, 2001; Douglas et al., 2010; Castelnuovo et al., 2012), they may also contribute to other inaccuracies if other local contextual factors affecting the care process are overlooked in the design of the EMR.

As mentioned previously, the users generally perceived that entering data in the EMR was ‘easier’ and ‘faster’ than writing in the health passports. Therefore, it can be perceived that the EMR system was inline with the recommended design principle of ‘*ease of use*’ (Ginneken et al., 1997). Though not specifically indicated by the health workers, the
perceived ease of use could be partly attributed to the touchscreen interface, the wizard-like approach and the extensive use of predefined lists/options rather than free text, such that the data entry required simply selecting an option rather than typing. This has been identified in other studies (Msukwa, 2011). The use of such predefined options has also been advocated for previously (Guest & Conrick, 2006; Douglas, 2009). However, other studies have also perceived the limited use of free-text as a challenge to the use of EMRs, particularly among clinicians/doctors who seem to prefer more narrative notes (Tang & McDonald, 2001; Msukwa, 2011). Thus, the use of structured data entry may be appropriate for Antenatal care services, since structured recording is already part of the work practice with the paper-based records. It may also be a general preference among specific cadres of health workers.

6.1.2 The DHIS Tracker EMR system

6.1.2.1 The Retrospective Approach

The DHIS Tracker system was guided by the underlying principle of being a basic transactional system, for managing and analysing transactional data, rather than an EMR system directly supporting the clinical care process. In this regard, the aim of the system was to serve more as a replacement of the health facility registry books. This implies that a retrospective use pattern is inscribed in the system. This is because it is often the case that data entry in the registers is done by support staff, such as Maternity hospital attendants, even though the nurses are the ones expected to enter data in the registers. The nurses are unable to do this task due to high workloads. It, therefore, follows that in our implementation of the DHIS Tracker, the entry of data in the system was mainly done by the hospital attendants and HSAs rather than the nurses. In addition, although attempts were made to include registration of clients within the ANC activities that were conducted (concurrently) before the clients’ consultations with the nurse, the evaluation revealed the health workers opted to do the registration at the end of the services, together with the entry of the visit data. This could be considered to be due to the retrospective data entry perspective associated with the ANC registers.

Similar to other EMR implementations presented in literature, e.g. (Castelnuovo et al., 2012; Ngoma et al., 2012; Thompson et al., 2010), the use of the DHIS Tracker occurred in parallel to the paper-based IS. As such, one of the effects perceived by the health workers was increased workload as they had to enter data into the DHIS Tracker and also the register book. This work was mainly increased for the hospital attendants. Furthermore, the HSAs were previously not involved in registration of ANC clients, thus this was a new task for them.
addition, other hospital attendants from the OPD were trained on using the system, and were therefore expected to be involved in the registration of ANC clients. Hence, collaboration with other health workers was increased following the introduction of the system, and so was the need for coordination. This coordination was not properly achieved as some health workers did not participate in the registration of clients in the system, which led to frustrations by other health workers. Part of it was attributed to the lack of a timetable and thus a proposal was made to formulate a timetable in order to share the registration work among the health workers. This could be perceived as a way to coordinate their work. At the same time, the lack of participation was also attributed to limited number of workstations that hindered opportunities for the others to assist in the work. In this regard, the available hardware did not fully accommodate the increased collaboration with the other health workers.

6.1.2.2 The functionality
The DHIS Tracker system consisted of functionality for registration of the patient/clients with a possibility for specifying different types of IDs for the clients. A system unique identifier was also generated automatically; however, this unique ID could only be viewed when viewing/editing the client’s profile. The system also had provision for specifying an identifier e.g. a national patient ID or a ANC registration number. Therefore, to retrieve the client’s record in the system, different criteria could be used for searching including the name or any of the specified identifiers. Thus, the system provided flexibility which is a recommended design principle and feature (Ginneken et al., 1997; Ngoma et al., 2012). However, in this case, the evaluation of the system showed that the users faced challenges in searching for clients in the system due to various factors. One of the factors was related to low computer literacy, such that the users often forgot to indicate or change the search criteria i.e. whether they were searching by the name or ANC registration number. As a result, when searching, the client could not be found because it was searching on the wrong information. Hence, in this regard, the provided flexibility did not work well with the low literacy levels of the users.

Another factor that made searching for clients challenging, was inconsistency in spellings of the clients’ names. In particular, there were often differences in the spelling between the client’s name entered in the system, and the name recorded on the clients’ health passport. As a result, the client’s record would not be found if the spellings did not match. In this regard, the system did not support coordination of work between the different health workers, and coordination over a period of time, which resulted in duplicate accounts being created for the same client. Previous studies have highlighted the need for unique patient ID systems due to
lack of national identification systems in Developing Countries (Rotich et al., 2003; Douglas, 2009; Piette et al., 2012). Although efforts were underway to develop a national patient identification system, as presented in paper 2, this had not yet been established. While the provision for different types of identifiers provided flexibility and could avoid the need to register clients for each service, there was still need for system generated unique IDs to accommodate the absence of national ID systems. Therefore the findings from this case reinforce the importance of functionality for issuing unique IDs to patients/clients in Developing Country contexts. In this case, the duplication in registration of the clients did not only negatively affect the accuracy of the data in the system; it also wasted the time of the clients and the health workers and contributed to delays in service provision.

Decision support functionality is another functionality considered important in the design of EMR systems (van Bemmel et al., 1997; Tang & McDonald, 2001; Kamadjeu et al., 2005; Douglas et al., 2010; Oluoch et al., 2012; Blaya et al., 2010; Msukwa, 2011). However, since the DHIS Tracker was not designed to support the clinical care process, the design did not provide for decision support during consultations with clients. Nevertheless, the protocols for ANC were still incorporated, for instance, in the scheduling of the visits. The scheduling was based on an LMP specified during enrolment and thus, the LMP was a mandatory data element. The system provided for the possibility to change the scheduled dates and this was conducive since the LMP was not always accurate. In addition, validations on individual and related data elements were also incorporated. Thus, the system had weak and strong inscriptions of the protocol.

Furthermore, the system included functionality for monitoring the progress of the visits through colour coding in order to indicate if the client’s visit was, for example, overdue. In turn, this could be used to prompt for reminders or follow-ups. In this regard, the system provided for some form of retrospective support of the care process. This suggests that decision support does not occur only during client consultations but can also take place retrospectively. However, this functionality was not used by the health workers as conducting follow-ups on ANC defaulters was not part of the work practice at the health centre. One health worker explained that it would be challenging to conduct follow-ups on defaulters because they received many ‘visiting’ clients (i.e. clients who started ANC elsewhere and/or were residing outside the catchment area of the health centre). This was due to easy accessibility of the health centre. Nevertheless, this functionality for follow-up could have been useful for the HSAs who conducted home visits for clients in their catchment areas as
part of a Community Based Maternal and Neonatal Health programme, as described in paper 1.

6.1.2.3 The Interface Design
The interface design of the DHIS Tracker adopted a form-based interface for data entry, as described in paper 6. The implementation adopted the use of a keyboard and mouse as input devices, even though the device that was used as the monitor was a touchscreen. The keyboard and mouse were considered appropriate for the forms that had been designed.

The evaluation of the system in use identified several challenges, which are presented in paper 6. Some of the health workers indicated that they had not mastered using the system and indicated they faced challenges in, for instance, connecting the devices, logging on, and scrolling on the forms. This can be considered an indication of a lack of ease of use and ease of learning of the system (Ginneken et al., 1997). However, the reasons for this situation can be seen to be partly due to the fact that the computer literacy among the health workers was low as they did not have prior experience or training in using a computer in general (even though a short basic introduction to computers had been provided during the training at the health centre). Thus, some of the health workers indicated that they had forgotten what they had learnt during the training and wanted a refresher course. At the same time, some of the health workers attributed the challenges to low education levels in general, such that they required more time to learn how to use the system. Furthermore, another contributing factor to the ‘forgetfulness’ was the gap in use of the EMR system when the system was down for almost 2 months, due to problems with the power solution. Ultimately, this indicates that considerable investment is required in training the health workers in basic computer use, as recommended in previous literature (Rotich et al., 2003; Ngoma et al., 2012). Considerations also need to be made on the education levels of the health workers as there is a possibility that those with low education may require more time in training and in support.

The design of the data entry forms for the visits was such that they also displayed data for the previous visit; for instance, the data entry form for visit 4 showed data that had been captured for visit 1 to 3. This was considered as a way of providing a quick overview of all the care provided, since the nurses had been the expected end-users during the design process. However, this resulted in forms that required scrolling horizontally and vertically during data entry. Scrolling was a challenge for most of the health workers as already mentioned, which often led to the health workers missing some data elements during the data entry. Thus,
reducing the density of the information on the data entry forms, as recommended by Guest & Conrick (2006), would’ve been appropriate especially since the data entry was retrospective. Fortunately, in the existing implementation, some of the skipped data elements had been indicated as mandatory fields and therefore alerts were provided whenever they tried to complete the form. Such validations were perceived by the health workers as one advantage of the EMR over the paper-based system since it prevented gaps and errors in the data. However, not all errors and gaps could be prevented as some were due to misunderstanding of the data values by the support staff. This challenge is one of the reasons that some implementers argue for point of care EMRs (Douglas, 2009; Castelnuovo et al., 2012).

Furthermore, one of the perceived effects of ‘not mastering’ how to use the system was increased time for the registration work, which resulted in clients going home late. Previous studies have also indicated that it should be expected that the deployment of EMRs will increase the service delivery time especially in the early days of use (Kamadjeu et al., 2005). In our case, the increase can also be attributed to the double registration work. Still, it should be noted that some health workers perceived entering data in the system to be faster than writing in the registers, despite the observed delays.

6.1.3 Implications for Design
Based on the discussion of the two cases, several implications for the design of EMR systems for use in rural primary care settings, or low resources settings in Developing Countries, can be drawn. These are summarised below.

6.1.3.1 Design for Collaborative work
The two cases have shown that deploying EMRs can increase collaboration among different types of health workers in the provision of Antenatal care services in rural primary care health facilities. In addition, due to the high workloads in such facilities, the work activities may occur in a concurrent manner rather than a linear workflow as is often the goal (Fraser et al., 2005; Douglas et al., 2010; Frean, 2006). Consequently this can increase the need for coordination between the health workers. As Berg et al. (2003) indicate that ICTs should be designed to fit the specific nature of healthcare work, it is, therefore, important that the EMR design should support the coordination of the work. This support relates to both the hardware and software design. The hardware design should ensure that the health workers have the required access to the EMR, and the software design should facilitate awareness of the work done by other health workers. Furthermore, there is need for mechanisms at an organisational level for coordinating the work, such as the proposed work time tables in these cases.
The collaborative nature of healthcare work has been recognised in previous studies from Developed Countries (Fitzpatrick & Ellingsen, 2012). Hence the need for EMRs to support coordination of work among different health providers is advocated for (ibid.). Adding on to this, the findings from this research revealed that cooperation with clients was also an important part of Antenatal care work. Due to limited healthcare resources and infrastructure in the health facilities, the clients played a central role in the provision of care which inevitably influenced whether health providers were able to provide care according to the care protocol. In this regard, it is important to take into consideration social contextual aspects relating to the clients such as language, culture and care seeking practices when designing EMR systems. For instance, in both cases, an indication of the accuracy of LMP date, i.e. whether it was the actual date or an estimate, could have been beneficial in determining whether to schedule the visits for that particular client based on the gestation calculated from the LMP, or from the fundal height.

6.1.3.2 EMR Functionality
The two cases represent two different approaches to the implementation of EMRs, with the Baobab ANC aiming at integrating the EMR in the clinical care process whilst the DHIS Tracker aimed at being a basic transactional system. Thus the underlying goals of how to support health services, and their inscribed patterns of use, were different. For instance, the Baobab ANC system aimed to provide clinical decision support at the Point of Care and inscribed a real-time pattern of use, while the DHIS Tracker was designed for retrospective use and support of the care process. Nevertheless, there are several important issues common in both cases.

In both systems, client registration was an important functionality. In addition, the ability to retrieve the client record by different users or during the next visit was crucial. The Baobab system included functionality for generating and printing a unique ID for the client in form of a barcode. Harmoniously, the system included functionality for searching the client by scanning the bar code or by searching the name. This functionality enabled easy and quick retrieval of the client’s record. On the other hand, although the DHIS Tracker generated a unique system ID, this was not easily accessible for the users and thus, could not be transferred/ transcribed to the health passport. In this regard, the use of IDs was dependent on having another paper-based system for assigning the IDs, e.g. service registration numbers. The lack of the IDs made it challenging to retrieve client records using names because of inconsistent spelling of names, coupled with low computer literacy of the health workers. This
reinforces, the importance for EMR systems to incorporate automatic generations of unique IDs for clients (Douglas, 2009; Piette et al., 2012) in order to reduce the risk of multiple registrations of clients.

In addition, the cases highlight the importance of integrating EMR systems with the existing paper-based system in order to eliminate duplication of registration work as the health workers are already faced with challenges of high workloads. In the Baobab system, the provision of printouts reduced the need for double recording of data in the EMR and in the health passport. However, it was not fully integrated with the paper-based system as they still had to record in the registers. Similarly in the DHIS Tracker, the implementation did not install a printer to provide for printing of the visit data, although functionality for printing was available in the software. Thus the system was not integrated with the paper-based system in a manner to reduce duplication in data capturing. At the same time, the flexibility provided by the DHIS Tracker in relation to accommodating different IDs for the patient can be perceived as a way of integrating with other existing paper-based systems. However, such flexibility did not work well in our context of implementation.

Furthermore, as already indicated, decision support functionality was incorporated in both systems, e.g. in form of alerts and reminders on required care. This involved inscribing protocols in the system. There are varying degrees in which the protocols can be inscribed, i.e. either as weak inscriptions or strong inscriptions. The ability to inscribe a weak or strong inscription is influenced by various contextual factors affecting the healthcare work including available resources and client practices. Nevertheless, the existence of validations was perceived positively by the health workers in both cases and therefore is important to incorporate.

6.1.3.3 Interface Design
The interface designs for data entry in the two systems can be seen to represent two extremes in terms of the density of information presented on a screen (Guest & Conrick, 2006). The Baobab system resolved to the collection of one data element per screen whilst the DHIS Tracker had a form design that had the visit data on a single form. The form design was guided by the design of the ANC page in the health passport. In addition, the Baobab system utilised the touchscreen for input whilst the DHIS Tracker utilised a keyboard and mouse. In general, the health workers using the Baobab system perceived it to be easier and faster than writing the data; thereby implying ‘ease of use’ of the system (Ginneken et al., 1997).
However, for the DHIS Tracker, the health workers indicated they still had not been able to master using the system which made them slow, which could imply a lack of *ease of use* and *ease of learning* of the system (Ginneken et al., 1997). Nevertheless, the reasons for these perceptions cannot simply be attributed to the design alone; rather, the personal attributes of the users (e.g. education levels) also play a role, as it was observed that some health workers also perceived the DHIS Tracker to be faster than writing. In addition, consideration has to be made that the DHIS Tracker was not in use for several months. Still more, the incorporation of some logic between related data elements that allows for skipping some data elements (if they are not relevant for that case) is a useful feature for EMR systems. This could save time in data collection as well as ensure consistency between the data. Furthermore, the use of structured data entry which utilises predefined options can be considered more appropriate for services where data is mostly collected in a structured format rather than as narratives, as was the case in Antenatal care.

However, a common challenge faced by health workers in both systems was the editing or correcting of erroneous data. In the Baobab case, this challenge was attributed to the long process for correcting visit data, which involved re-entering all the data elements within that specific group of data elements. Due to this, there were inconsistencies between the data in the EMR and what was in the health passport. Thus, while the grouping and wizard-like approach may have contributed to the perceived ease of use of the Baobab ANC system, it also created challenges for correcting erroneous data. This highlights how recommended design principles can have both, negative and positive effects on health services.

In the DHIS Tracker case, the challenge was mainly observed in correcting the client’s information that was captured during registration. This was attributed to low computer literacy among the users. Hence, the cases reemphasizes the need for EMR systems to be designed in a way that allows for easy correction of erroneous data as recommended by (Ginneken et al., 1997); bearing in mind the level of computer competency among the health workers and their high workloads.
6.2 Participatory Design
The second research question of this study relates to the issue of user participation in EMR systems development processes and is expressed as:

*RQ2: What is the nature of user participation in the development of Maternal health EMR systems for use in rural primary care settings?*

To answer this question, I examine the role of the users in the development processes and the challenges in participation.

The development processes for the EMR systems have been presented in papers 4 and 5 of this thesis. These processes differed in that the Baobab ANC system was developed locally in Malawi, whereas for the DHIS Tracker system, the process involved local customisation of a generic software that was developed by a team distributed globally. Paper 4 presents analysis of the participation of different stakeholders and this was possible due to the relatively small scale nature of the project as well as the central role I had in the project. However, for the DHIS Tracker project, it is challenging to analyse the participation of different stakeholders in a globally distributed project with the peripheral role I assumed. Therefore, with regards to the DHIS Tracker development, I mainly focus on user participation within the local context and our role of researcher-designers, acting as representatives of the local end-users, within the global context.

6.2.1 User Participation
As presented in the research methodology, the local development and customisation processes of the two systems originated from a common diagnosis of Maternal health services within the public health system. During this analysis, health workers assumed an *informative* role, providing information on the work practices, information and communication requirements, and challenges faced in their work. The situation analysis involved a wide range of health workers in several facilities.

Once the decision had been made by the research team to develop EMR systems, three specific health centres were identified for implementation and therefore further participation was mainly sought from health workers within these facilities, particularly those who were expected to be the end-users of the systems. Nevertheless, as presented in paper 4, other stakeholders also participated in the process including health workers from two urban hospitals, managers at district level, and health service partners. Table 6.1 summarises the
participation of the health workers, as the intended end-users, in the two systems’ development processes.

Table 6.1: Summary of end-users’ participation

<table>
<thead>
<tr>
<th>Attributes of Participation</th>
<th>End-user participation in Baobab ANC development</th>
<th>End-user participation in DHIS Tracker development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local level</td>
<td>Global level</td>
</tr>
<tr>
<td>Type</td>
<td>Direct- User Representative</td>
<td>Direct- User Representative</td>
</tr>
<tr>
<td></td>
<td>Indirect- represented by researcher- designers</td>
<td>Informative, consultative</td>
</tr>
<tr>
<td>Degree</td>
<td>Informative, consultative, decisive</td>
<td>Informative, consultative, decisive</td>
</tr>
<tr>
<td>Extent</td>
<td>Requirements analysis, Software review/ testing, Hardware installation, User training, System use</td>
<td>Requirements analysis, Software review/ testing, Hardware installation, User training, System use</td>
</tr>
<tr>
<td></td>
<td>Informative, consultative</td>
<td>Software customisation, Software review/ testing, Implementers’ training, System use</td>
</tr>
<tr>
<td>Content</td>
<td>Service workflow, Data elements, data values &amp; validation rules, Software logic, interface design &amp; functionality, Hardware installation locations &amp; usability Identifying end-users</td>
<td>Service workflow, Data elements &amp; data values, Software functionality, Hardware installation locations Identifying end-users</td>
</tr>
<tr>
<td></td>
<td>Software functionality</td>
<td>Software functionality</td>
</tr>
<tr>
<td>Formality</td>
<td>Formal approval of project at national and district levels, Informal arrangement on users’ participation, Some discussions held in formally organised meetings/activities</td>
<td>Formal approval of project at national and district levels, Informal arrangement on users’ participation, Some discussions held in formally organised meetings/activities</td>
</tr>
<tr>
<td></td>
<td>Informal arrangement with HISP on participation and support, Discussions held in official meetings and through informal relationships</td>
<td>Informal arrangement with HISP on participation and support, Discussions held in official meetings and through informal relationships</td>
</tr>
<tr>
<td>Influence</td>
<td>Software functionality &amp; interface design, Hardware design, Security requirements, Service workflow, task-shifting, scope of system use</td>
<td>Data requirements, Software interface design, Hardware design, Service work flow</td>
</tr>
<tr>
<td></td>
<td>Software functional requirements ignored/considered.</td>
<td>Software functional requirements ignored/considered.</td>
</tr>
</tbody>
</table>

As shown in Table 6.1, there are similarities in the type, degree and extent of participation of the end users in the two projects, at the local level. However, differences can be seen in terms of the content and resulting influence of their participation. In the Baobab EMR process, the content of the end users participation covered a broader scope which included validation rules, software logic and the interface design; whilst in the DHIS Tracker case, these issues were not covered. As a result, the end-users involved in the Baobab case influenced more aspects of the EMR system when compared to aspects that were influenced by the end-users.
involved in the DHIS Tracker case. There are three possible reasons why this was the case. Firstly, this could be attributed to the research design in that the development of the Baobab EMR was chronologically the first system, and therefore, by the time customisation of the DHIS Tracker was undertaken; designers had already gained considerable knowledge on the health domain, such as the ANC protocol, data requirements and required validation rules. Another reason for the difference in the scope of influence could be related to the different designs of the software themselves as described in section 6.1. For instance in the DHIS Tracker software, the design of the software did not incorporate specifying the workflow for a particular visit as it was rather aimed for retrospective data entry, whilst the Baobab system design focused on defining the workflow. The third reason for the difference, particularly on lack of influence on the software functionality in the DHIS Tracker can be attributed to the challenges of influencing the design of a generic software that is globally developed, as presented in paper 5, which included communication challenges and low prioritisation of local requirements. Thus, the ability of the users (and the designers) to influence certain aspects of the software design was limited.

In terms of the formality of participation, it is somewhat challenging to characterise participation in terms of formal or informal, as what can be considered as formal and informal is not clear-cut but is subject to what (or whose) perspective is taken. In this study, the project was officially approved at national and district levels and thus, the health workers’ participation in all activities undertaken in the project can be viewed to have been formal. In addition, formally organised activities such as demonstration meetings and trainings were undertaken. However, no formal design group or team was officially established that indicated health workers as part of that design group and their corresponding roles/responsibilities, as is inferred by Cavaye (1995). In this sense, it can be viewed as the health workers’ participation was not formally established. Furthermore, when looking at users’ participation in the DHIS Tracker development through us, researcher-designers, no specific arrangement was made between us and the global team to define our participation, rather, our participation was implicit, i.e. by being researchers at the University of Oslo. In this regard, our participation could be considered informal. However, some of the HISP activities we participated in such as meetings and workshops were officially organised which can make our participation to be perceived as formal. Thus, characterising the formality of participation is challenging.
Furthermore, the analysis of the users’ participation shows that the degree of participation was not consistent throughout the development process. For instance, in both cases, at local level, the degree of participation was rather informative initially but evolved, becoming more decisive in the latter phases of development. This is in contrast to the general expectation of PD projects, which is to have users involved in decision-making, i.e. taking on a decisive role, throughout the development process (Bødker et al., 2004; Robertson & Simonsen, 2012). Although the decisive role is the most desirable degree of user participation, it is not always possible to achieve this throughout the design process due to contextual factors posing challenges.

In particular, in the context of Developing Countries, one of the challenges is the lack of computer skills and limited exposure to IT among users groups (Kimaro & Titlestad, 2008). This lack of skills can limit the ability of the users to effectively participate during system development processes, especially in the early phases when the system is rather abstract (ibid.). In this study, another challenge for participation that was identified was the lack of the required health domain knowledge among some of the expected end users within the rural primary care settings. This is in conflict with the assumption that the end users are the experts of the work domain, as is usually the case in western countries (Schuler & Namioka, 1993; Bødker et al., 2004). As presented in paper 4, some of the expected end users lacked the domain knowledge because they were not involved in the provision of Antenatal health services prior to deployment of the systems, thus it was a new domain for them. In addition, some of the end-users who were involved in service provision, and were therefore expected to have the domain knowledge, had limited understanding on some of the data requirements. In this regard, managers and other health experts supplemented this lack of knowledge.

An important finding from both cases is the challenge in defining the user group based on existing work practices. As the cases have shown, whilst the nurses and Maternity hospital attendants were defined as the end-users during the early stages, other health workers such as the HSAs and clerks were later included as part of the user group. In addition, as presented in paper 4, the user group co-evolved with changes in the software design. This reveals that it is challenging to identify all the ‘right users’ (Kimaro & Titlestad, 2008) or to predefine a fixed user group to participate in development process as recommended by Bødker et al. (2004).
6.2.2 The role of researcher-designers
The role of researcher-designers as mediators has been identified in previous literature (Iivari et al., 2009; Braa & Sahay, 2013). The roles I assumed in the two cases reflect two forms of mediator roles in Participatory design processes. In the Baobab case, I assumed full responsibility of the project and was therefore responsible for mediating and negotiating the requirements from different stakeholders. As such, I was at the centre of decision-making in the development process. From this role, the study reveals the challenges that designers encounter in identifying stakeholders and in trying to incorporate perspectives of different stakeholders in the system design.

On the other hand, in the DHIS Tracker case, we, researcher-designers, acted as user representatives in the global software development project with limited decision-making power on the emergent software design; similar to experiences reported by Iivari (2011). The customisation of generic software is meant to enhance local participation and provide designers and users decision-making power on local requirements by enabling easy and quick incorporation of local requirements (Kimaro & Titlestad, 2008; Staring & Titlestad, 2008; Titlestad et al., 2009; Braa & Sahay, 2013; Gizaw, 2014). This, in turn is expected to keep users active and motivated to participate (ibid.). However, in our case, other requirements needed further software coding, which could not be done locally, but rather involved a time-consuming process without guarantees that the requirements would be incorporated. Thus, instead of keeping users active and motivated to participate, engaging the users further was challenging and users were frustrated as their requirements were not addressed. This highlights the challenges of mediation as a PD strategy, in a Distributed Software Development project that is highly dependent on mediators, and the need for additional strategies to enhance participation.

6.2.3 Implications for Participatory Design processes
There are several implications that can be drawn from these two cases to inform Participatory Design processes. Some of the implications relate specifically to the development of EMR systems for low resource settings in Developing Countries, such as rural primary care facilities. Other implications relate to Distributed Software Development (DSD), such as the development of Free and Open Source Software, which is being widely adopted in Developing Countries. These implications are summarised below.
6.2.3.1  **EMR systems development for rural primary care settings**

In order to address the challenges faced in participation, it is important that the development process allows flexibility in terms of who participates within the process. This is important considering challenges in defining the user group based on existing work practices, since the user group co-evolves with the emergent design. One way to ensure that participation is open to others is by anchoring visions, which is a way of involving other staff members, as proposed by Bødker et al. (2004).

In addition, due to challenges of limited availability of highly qualified professionals in rural primary care settings, it is important to allow for contributions from other stakeholders such as managers and other health experts to supplement the lack of knowledge among the end users. The findings, therefore, re-emphasise the need for involving different types of stakeholders beyond perceived end-users, as recommended previously (Byrne & Sahay, 2007; Puri et al., 2009). This, however, does not imply that participation of the expected end users should be disregarded in favour of expertise located elsewhere. It is still important to involve expected end users in the process as this could also provide learning opportunities for less experienced or qualified health workers about recommended healthcare practices, and more understanding of the basis of certain design features or decisions, e.g. validation rules. Nevertheless, this also presents a risk that social inequalities (Byrne & Sahay, 2007) between the expected end-users and highly qualified health workers might intimidate the end-users and lead to their limited participation in mixed forums. Furthermore, other stakeholder groups might dominate others (Igira, 2008). Hence, involving the different stakeholder groups requires strategies that will provide room for effective participation of the less qualified health workers. In this study, initial participation focused on the expected end-users’ work practices and managers and other experts participated later on. In addition, some demonstration sessions were held with the users only which provided room for them to give their input without interference of the experts’ views. Hence there is need to seek stakeholders’ participation separately, as well as in mixed forums.

At the same time, it is important to note that even without direct participation; stakeholders can still influence the design of the EMR system. For instance, even without direct participation or representation, considerations with regards to the clients’ practices as well as donor interests influenced the emergent design of the EMR systems. Thus participatory design processes should not only focus on those performing the work, it should also consider the stakeholders that affect how the work gets done.
6.2.3.2 PD in Distributed Software Development projects

Participatory design in globally Distributed Software Development (DSD) projects faces challenges caused by geographical and organisational distribution and therefore requires additional efforts. The case of the DHIS Tracker system reveals the need to enhance the role of mediators so that they are able to influence the emergent software design. This can be achieved by extending mediators involvement to include voting on prioritisation of requirements submitted from different contexts, as was done in the case of D'Andrea et al. (2008). This would also reduce having requirements incorporated based on the formal positions of the mediators (i.e. whether student researcher, information manager etc.) or the size (and perceived value) of their associated project.

In addition, recognising that not all local requirements may be incorporated in the design of a generic software system, it is, however, important to be transparent on how the requirements were considered in making the design decisions. Thus, communicating on how the requirements were handled in the design decisions is an important part of PD processes. This need for communicating design decisions and underlying design principles has been presented previously by Obendorf et al. (2009) who propose the use of commented case studies.

The DHIS Tracker case also shows that local software development is still required to allow swift response to users’ requirements at local levels. Hence there is need for local software development capacity and a software architecture that allows for considerable independent local software development.
7 CONTRIBUTIONS & CONCLUSION
In concluding this thesis, this chapter summarises the contributions from this research. It presents the contributions the study makes to the reference disciplines of Health Informatics and Participatory Design. Lastly, concluding remarks are made that propose areas for future research.

7.1 Contributions to Health Informatics
This thesis contributes to Health informatics research in Developing Countries mainly in three ways. Firstly, it contributes to the understanding of the nature of maternal healthcare work in low resource settings such as rural health centres in Malawi. Secondly, it contributes to the understanding of the effects of EMR systems on Antenatal Care services in rural primary care settings. Thirdly, it identifies design principles and strategies that support the use of EMRs within these settings.

7.1.1 The nature of Maternal healthcare work
The research contributes to the understanding of the nature of Maternal healthcare work in relation to the development of EMR systems for use in rural primary care settings, in a Developing Country context. The study re-emphasizes the collaborative nature of healthcare work between different health workers, similar to the findings in western contexts (Fitzpatrick & Ellingsen, 2012; Ellingsen & Monteiro, 2003). In addition, the study highlights the role of clients within the healthcare process and therefore argues that clients should be perceived as cooperative actors in maternal healthcare work. This implies a need to pay attention to the role of clients (in addition to the roles of health workers) when analysing healthcare work to inform design of EMR systems.

7.1.2 Effects of EMRs on Antenatal care services
The study contributes to the understanding of the effects of EMRs in the provision of Antenatal care services in rural primary care settings. In this regard, the study adds on to the body of literature of the effects of EMR systems in Developing country contexts, which has mostly focused on other healthcare domains, e.g. HIV/AIDS (Fraser et al., 2005; Fraser & Blaya, 2010; Kamadjeu et al., 2005; Rotich et al., 2003; Chi et al., 2011; Singh et al., 1997; Douglas, 2009; Thompson et al., 2010; Waters et al., 2010; Castelnuovo et al., 2012; Ngoma et al., 2012; Anantraman et al., 2002;Were et al., 2010b).

The study reveals that introducing EMRs in provision on Antenatal care within rural primary care settings increases the collaboration between different types of health workers in the healthcare work. Due to this, it also increases the organisational attention on the healthcare
domain and increases the knowledge of the health workers on the healthcare domain. Furthermore, introducing EMRs redistributes risks in care and in data quality by reducing the risk of errors in some areas whilst increasing the risks in other areas.

7.1.3 Design principles and strategies
The thesis examines the appropriateness of design principles and strategies that have been recommended in previous literature on EMR systems development in general, e.g. (Ginneken et al., 1997; Tang & McDonald, 2001; Guest & Conrick, 2006), and in Developing Countries, e.g. (Fraser et al., 2005; Douglas, 2009; Ngoma et al., 2012). It analyses how some of the design principles contributed towards the emergent use of the system and the perceived effects of introducing the EMR systems in those settings. Through this analysis, the thesis identifies how the design principles and strategies supported the use of the EMRs in provision of Maternal health services within rural primary care settings. In particular, the study highlights the need for designs that: support concurrent work activities and coordination of work; generate unique patient IDs; integrate EMRs with paper-based systems, utilise structured data entry, and incorporate validations and branching of data. At the same time, the study highlights how perceived ‘good designs’ can have both, negative and positive effects on health service provision, when other contextual factors, such as clients’ culture and language, are overlooked.

Furthermore, the research also highlights contextual factors that affect the development of EMR systems in relation to decision support functionality. These factors include staff shortages, lack of medical supplies and client practices. This results in the incorporation of decision support functionality in form of weak and strong inscriptions of the protocol. The study, therefore, proposes viewing the extent to which decision support functionality is incorporated in EMR systems (Car et al., 2008) in terms of the strength of the inscriptions.

7.2 Contributions to Participatory Design
Broadly, the thesis contributes to Participatory Design by providing a Developing Country experience of PD. The contributions relate to understanding of the nature of user participation and the role of researcher-designers in EMR systems development.

7.2.1 The nature of user participation in EMR systems development
This study contributes to the understanding of nature of user participation in the development of EMR systems in Malawi. Bearing in mind that PD is highly contextual (Puri et al., 2004), it is important to understand the challenges and strategies for PD in the Malawi context.
Additionally, the need for and effectiveness of user participation can vary across different types of systems (Lynch & Gregor, 2004). The study therefore contributes by presenting an analysis of participation of different types of stakeholders in the development of EMR systems for rural primary care settings in Malawi. In so doing, the thesis links the stakeholders’ participation to design outcomes and therefore addresses one of the gaps of PD research, which is the link between design processes and the outcomes (Puri et al., 2009; Balka, 2010).

In addition, the thesis identified challenges of participation for users in rural primary care settings. One of these challenges was the limited knowledge of health workers on the health domain which affected their ability to contribute in defining data requirements. Furthermore, the thesis highlights the challenges in identifying the ‘right users’ to participate in EMR systems development due to the evolving nature of the user group, which is contrary to recommendations from previous literature (Bødker et al., 2004; Kimaro & Titlestad, 2008). The thesis therefore highlights the need to leave participation open for the contributions of different types of stakeholders to supplement limited knowledge among end-users, and to accommodate co-evolution of the system design and the user group.

7.2.2 The role of Researcher-designers in Distributed Software Development

The thesis contributes to understanding the nature of participation for researcher-designers, acting as mediators, in Distributed Software Development of an open source software. Previous literature has highlighted the importance of mediators, such as researchers, implementers and HCI specialists, in DSD (Tuovila & Iivari, 2007; Barcellini et al., 2008; Iivari et al., 2009; Titlestad et al., 2009; Braa & Sahay, 2013). This study adds on to the existing literature by examining the challenges in mediation and effective role of mediators in a DSD project from a researcher-designer perspective. In our case, as researcher-designers, we had considerable decision-making power during the customisation process at local levels, but had limited decision-making power on the incorporation of local requirements into the software at global level. Mediators in previous studies have also been found to have limited decision-making power on the software outcome (Tuovila & Iivari, 2007; Barcellini et al., 2008; Iivari, 2011). This study, further, reveals the consequences of such limited influence on local projects. In particular, challenges in getting local requirements incorporated in the software design at a global level negatively influenced the progress of the project and the design outcome, i.e. the implemented system had missing required functionality. This, in turn, led to frustration for the users. The study, therefore, highlights the need for additional efforts
to enhance participation, which includes involving mediators in prioritisation of requirements and enhancing local software development capacity.

### 7.2.3 Forms of Participation

The thesis contributes to PD through the application of the dimensions/attributes of participation proposed by Cavaye (1995), which are *type, degree, extent, content, formality* and *influence*. These dimensions have previously been used to examine participation of users in western contexts, e.g. Lynch & Gregor (2004). This study has applied the dimensions to analyse participation of users and other types of stakeholders in a Developing Country setting. Through this analysis, the study identifies problems in predefining the full user groups in design processes which presents difficulty in characterizing the *type* of participation in Cavaye’s framework.

The study also identifies challenges in defining the *formality* of participation due to the ambiguity in the definitions of what is formal or informal. This in turn, makes it challenging to characterize participation along this dimension.

### 7.3 Concluding Remarks

The initial goal of this study was to implement EMR systems to support Maternal health service provision in rural primary care settings. These services included Antenatal care, Delivery and Postnatal care. Due to time constraints, the research only managed to implement systems in the area of Antenatal care. Thus the findings on the development process and effects on healthcare work relate to experiences from one area of Maternal health care. The case may be different when looking at other services, for instance, conducting deliveries, which requires more clinical skills. Thus, further research is required to explore the development and use of EMR systems in other Maternal health services.

In addition, the envisioned ICT-based solution in this research consisted of EMR systems and mhealth applications, as presented in paper 1 of this thesis. However, the research was not able to implement the mhealth applications. Although such functionality already existed in the DHIS Tracker, the research did not utilise the full functionality of the software. Therefore further studies can explore the implementation and use of mhealth applications to support Maternal health services at both facility and community levels.

Furthermore, the functionality in the Baobab EMR system incorporated printing of the captured information. It is important to assess whether these printouts address the information
requirements of health workers in other facilities, for instance, in referral or neighbouring facilities that clients go to.

Lastly, the study has identified Antenatal clients as important stakeholders in Antenatal healthcare work. However, literacy levels are generally low among women in rural settings. Therefore, in trying to consider clients in the design of EMR systems, a new challenge for designers it to identify strategies for designing EMR systems that foster communication and cooperation between clients and health workers within these settings.
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Appendix 1: Paper 1

USE OF MOBILE TECHNOLOGY TO SUPPORT PROVISION OF COMMUNITY-BASED MATERNAL AND NEONATAL CARE IN DEVELOPING COUNTRIES

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Keywords: Community-based maternal and neonatal care, Community health workers, Mobile technology, Electronic health records, Developing countries, Rural areas, Malawi.

Abstract: The health systems in many developing countries in Africa are facing critical shortages in nursing and midwifery health professionals and the situation is worse in the rural areas resulting in poor maternal and neonatal health outcomes. One of the interventions to address this challenge has been the use of Community Health Workers to supplement the provision of maternal and neonatal healthcare services within their communities. The international community is advocating for the use of Mobile technology in supporting various health service areas including community-based healthcare. This paper presents findings of a research on the information and communication needs of Community Health Workers in the provision Community-Based Maternal and Neonatal care in the rural areas of a developing country, Malawi, and it examines the potential use for adopting mobile technologies in such a setting to meet their needs.

1 INTRODUCTION

Developing countries in Africa are struggling to make progress towards the achievement of health-related Millennium Development Goals (MDGs) particularly MDG 4 and 5 which are aimed at reducing child and maternal mortality (UNICEF, 2008). One of the challenges causing this is the acute shortage of nursing and midwifery health professionals which is particularly severe in rural areas due to poor infrastructure and working conditions (SaveTheChildren, 2010). In order to address this challenge, the international community recommends governments to scale up human resources for health including paid community health workers (MDGAfricaSteeringGroup, 2008). Thus, interventions are being implemented that involve Community Health Workers (CHWs) in the provision of Maternal and Neonatal Healthcare services at the community level; and countries such as Pakistan have already demonstrated the positive impact such interventions can make on improving health status of the community (GHWA, 2008).

The use of mobile technology to support various health services as advocated by the international community can be adapted for community/home-based healthcare and (Iluyemi and Briggs, 2010) indicate that supporting Community Health Workers with mobile information and telecommunication technologies should be considered a top priority within the e-health agendas of developing countries. Many studies on mobile-health (m-health) applications implemented in developing countries have reported their use to support HIV/AIDS and Child health services (Kinkade and Verclas, 2008; Manda, 2009; UNICEF, 2009; Vital Wave Consulting, 2009). However, limited literature exists on the application and use of such technologies to support Maternal and Neonatal Healthcare even though this is a high priority health area in developing countries. Therefore, this study was conducted to investigate the provision of Community-based Maternal and Neonatal healthcare services in a developing country, Malawi, with the aim of exploring the potential of using mobile technology to support service delivery. In particular, the research had four objectives:

1. To investigate the duties and activities of Community Health Workers (CHWs) in relation to maternal and neonatal health care.
2. Identify the information and communication needs of these CHWs in their work.
3. Identify the areas in which mobile health applications can be used to support their needs.
4. Define the design for a mobile-based maternal and neonatal health application.

Therefore, this paper presents the current activities of CHWs in the provision of maternal and neonatal health care at community level in Malawi and their associated information and communication needs. It further discusses the potential of using mobile technology to support the CHWs.

The study is part of an ongoing research on the use of ICT to support Maternal and Child Health service whose overall objective is to identify strategies, through action research, for designing and implementing ICT-based information systems for Maternal Health Care services in rural settings of developing countries.

2 RESEARCH CONTEXT - THE MALAWI HEALTH SYSTEM

This study was conducted in Malawi where the majority of the population (85%) is located in rural areas (NSO, 2008).

Healthcare services are mainly provided by the Ministry of Health and there are three levels of service provision in the health system: the primary level comprising of health centres, health posts, dispensaries, and rural hospitals; the second level is made up of district hospitals; and the tertiary level consists of the central hospitals and one private hospital with specialist services (ibid.). The health centre is the most easily accessible health facility and thus, it is where most women go to seek maternal health care. At this level basic maternal and child health services such as antenatal care, delivery (for normal cases), postnatal care, child immunisation, and family planning are provided and these services are provided by various groups of health professionals such as nurses, midwives, medical assistants and clinical officers (MoH, 2007; Sharan et al., 2009). The hospitals provide more comprehensive obstetric care therefore women observed with obstetric complications at health centres are referred to hospitals (ibid.)

The country is reported to have one of the highest maternal mortality ratios globally as it almost doubled between 1992 and 2000 from 620 to 1120 deaths per 100,000 live births (Sharan et al., 2009). Poor access and utilisation of services is one of the contributing factors to these high mortality rates and some of the barriers to the utilisation of maternal health care services include social and cultural/traditional beliefs and practices (Sharan et al., 2009). Therefore, one of the strategies of the Ministry of Health for addressing these problems is to establish and strengthen community initiatives for Maternal and Neonatal Health (MoH, 2007).

2.1 Community Health Workers in Maternal and Neonatal Care

There are different types of health workers involved in maternal and child health services within the communities both from the formal/modern health system and the traditional side. The traditional health system consists of women known as Traditional Birth Attendants (TBAs). The TBAs used to have more established links with the modern health sector as some had been trained to support primary health care (MoHP, 2001). However, in 2007, the TBAs role changed from a service provider for antenatal care and deliveries to a safe motherhood advocate to refer women to health facilities (Kanjor and Kaasboll, 2009).

The formal/modern health system has Community nurses, Health Surveillance Assistants (HSAs), and Village Health Workers involved in provision of community maternal and neonatal health service, having been recruited and associated with health facilities.

The community nurses are nurses in health centres responsible for organising and providing healthcare services in the community in addition to providing services at the health centre. These community nurses are expected to conduct outreach clinics to provide antenatal care services.

Village Health workers (VHWs) are volunteers who assist in various health programmes within their villages and their duties include following-up on PMTCT clients and facilitating community sensitisation on HIV/PMTCT. The VHWs also assist in identifying and registering pregnant women in the village and reporting births that take place in the village to the HSAs.

The HSAs are the main link between the communities and the health facilities; however, their involvement in maternal and neonatal health services has been limited as this was not established as part of their duties. The research discovered it was only in 2008 that the Ministry of Health in partnership with donors started the establishment of Community Based Maternal and Neonatal Care (CBMNC) by piloting in three districts in Malawi (Dowa, Chitipa and Thyolo). Therefore, the duties and activities of HSAs in relation to maternal and
neonatal health vary among the districts as well as the health facilities.

In this study, the focus was on the HSAs as they are the major link between the communities and the health facilities and current Government efforts are focusing more on their involvement in CBMNC.

3 RESEARCH METHODOLOGY

The study was conducted in three districts in Malawi namely Lilongwe, Dowa and Machinga. A total of 17 rural health facilities were visited, the majority being health centres (12). Other facilities visited were rural hospitals (3) and district hospitals (2).

A qualitative research approach was adopted in order to obtain a deep understanding of the work and activities of the HSAs and their related information and communication needs. Thus, qualitative data collection techniques such as interviews and document reviews were employed. Additionally, review of existing software applications in use for data management and communication was done.

To acquire information on the HSAs and their work in relation to maternal and neonatal health care; 26 nurses, 12 Health Surveillance Assistants and 2 district coordinators of the community-based maternal and neonatal healthcare programmes were interviewed individually. The interviews provided data on the community based programme activities and procedures, data collected, reported and the reporting systems.

Documents such as service registers, CBMNC programme forms and Village Health Registers were reviewed to obtain data on the information requirements of the HSAs and the programme.

4 M-HEALTH APPLICATIONS IN DEVELOPING COUNTRIES

The high diffusion of mobile technology in developing countries has led to the widespread conviction that the adoption of mobile applications can be beneficial in supporting health care delivery in developing countries (UnitedNations, 2007; VitalWave Consulting, 2009). Statistics indicate that in 2008, Malawi had 1.2 fixed phone lines per 100 inhabitants, mobile cellular subscription was at 12 per 100 people and the proportion of households with internet was 1.7, thereby indicating the diffusion of mobile telephony is higher than that of the Internet and fixed line telephones (ITU, 2010).

There are various ways in which mobile technology can be used to support health service delivery. According to Iluyemi and Briggs (2009), sustainable improvement in healthcare in developing country can be brought about by providing CHWs access to reliable health information and mobile applications present opportunities to complement conventional methods of accessing and disseminating this information effectively. Additionally, the mobility of CHWs activities can very much be accommodated by using mobile applications to meet their information requirements (Chatterjee et al., 2009). (Mechael et al., 2010) also indicate that m-health applications present an opportunity to break down the traditional information barriers between diagnosis and treatment and surveillance activities.

Furthermore, (Mechael et al., 2010) report that mobile technologies have been found to increase communication between health professionals and community health workers in developing countries through the use of voice calls and SMS applications thereby resulting in a collaborative support system and better patient care.

Several studies have presented various uses of mobile applications for improving health service delivery at community level in developing countries with most cases focusing on their use to monitor and support treatment for chronic infectious diseases such as HIV/AIDS and TB (Mechael et al., 2010; Kinkade and Verclas, 2008; Manda, 2009; United Nations, 2007). Other cases have also presented the use of mobile technology for collecting child nutrition data and the Integrated Management of Child Infections (IMCI) data within the community (DeRenzi et al., 2008; UNICEF, 2009). Literature on the use of similar applications to support maternal and neonatal health care has been limited thus indicating limited use of m-health applications in this health domain. The few cases presented portrayed how mobile devices such as Walkie-talkies and cell phones were being used for voice communication among service providers for referral cases as well as consultation on delivery cases (Musoke, 2002; Mechael, 2005).

Nevertheless, more recently, several cases have been presented which are focusing on using m-health applications to support maternal and neonatal healthcare in various ways including collecting data on the mother and infant’s condition for patient monitoring, referring the mother or infant to health
facilities and follow-up care (Dimagi; United Nations, 2007).

A summary of m-health applications and projects in use by community health workers is presented in Table 1 below. Even so, (Mechael et al., 2010) indicate there is need for studies that investigate the use and development of Electronic Health Records (EHRs) on mobile phones because EHRs have the potential to create a foundation for which the scope of m-Health can be realized.

5 FINDINGS

The findings of this study are on the activities of the Health Surveillance Assistants (HSAs) who were involved in Maternal and Neonatal Healthcare at community level and the associated information and communication needs for those activities. Four main activities of the HSAs were identified and are presented in the subsections that follow.

5.1 Follow-up on Antenatal Clients

The HSAs conduct follow-up on pregnant women within their communities and there are basically two types of follow-ups. The first type is follow-up on pregnant women who had attended antenatal clinic and were expected to have delivered in a particular month but they had not gone to the health centre for delivery. The second type is part of the PMTCT programme whereby follow-up is done on HIV positive pregnant women who have missed their appointments. The follow-ups are initiated by the health centre nurses who provide the clients’ residential details to the appropriate HSA. The HSA provide feedback on the follow-up in special cases e.g. if the woman has moved to another location.

In some health facilities, a mobile-based application, FrontlineSMS, is being used to communicate the details of clients needing follow-up to the appropriate HSA and/or VHW.

Table 1: Mobile-Health Applications used by Community Health Workers.

<table>
<thead>
<tr>
<th>m-Health Application</th>
<th>Functions</th>
<th>Goals</th>
<th>Countries Implemented</th>
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| CommCare             | - Manage household visits  
                      - Assist in planning daily activities  
                      - Record information on mother and child’s conditions and birth data  
                      - Transmission of data/information to a central repository  
                      - Referral of infant or mother in need of medical attention | - To provide better and efficient health care  
                      - Enabling supervision and coordination of community health programs  
                      - Enabling monitoring and evaluation of the community health programs | - Tanzania  
                      - Bangladesh (Dimagi; Lesh) |
| Nacer                | - Communicating and exchanging critical health information among health professionals for: patient monitoring, patient referral, follow-up care and disease surveillance | - To improve communication among health professionals  
                      - Share data with hospitals when referring patients  
                      - Receiving feedback for follow-up | - Peru (United Nations, 2007) |
| MoTeCH               | - Recording patient encounter information (i.e. mother/child assessment and treatment given)  
                      - Tracking of patients | - To increase the quality and quantity of antenatal and neonatal care in rural Ghana | - Ghana (Heatwole, 2010) |
| Cell-Life            | - Accessing real-time health records of ART clients  
                      - Collect information on drugs and side effects, and relevant socio-economic indicators.  
                      - Monitoring and providing feedback to the CHWs as required | - Management of the HIV/AIDS epidemic by providing real-time voice communication between the care manager and CHWs | - South Africa (United Nations, 2007) |
| e-IMCI               | - Provide decision support tool to guide health workers in the management of childhood illnesses based on WHO protocols | - Facilitate standardised diagnosis and treatment of common childhood illnesses. | - Tanzania (DeRenzi et al., 2008) |
| FrontlineSMS         | - Communicating patient condition and treatment given during home-based care  
                      - Provision of treatment guidance | - Enables communication and coordination among health workers on home-based care. | - Malawi (Manda, 2009) |
5.2 Provision of Community based Maternal and Neonatal Care

The HSAs are required to conduct household visits during the antenatal period and the early postnatal period, thus, they need to identify and maintain lists of all pregnant women within their catchment areas.

The HSA is expected to conduct at least three household visits to the woman during her pregnancy in which the following activities are done:

1. Review of the woman’s health record which is in form of a health passport.
2. Assessment of the client’s current health status by interviewing the woman. If danger signs are discovered, the HSA refers the client to the health centre.
3. Provide health education and counselling based on the findings of the review and assessment.
4. Develop a birth plan to help the woman prepare for delivery and the newborn.

The HSA is also required to make at least three visits at home after delivery and within 8 days after delivery, the first visit being day 1 after delivery especially for home deliveries. In order to make these visits in the appropriate timeframe, the HSA needs to be informed when the delivery has occurred. This is done by either the woman’s guardian, a village health committee member or a VHW who sends a message or either visits the HSA in person.

During the postnatal visits, the following activities are conducted by the HSA:

1. Obtain the labour and delivery details by reviewing the health passport if a delivery occurred at a health centre. Other details are also obtained from interviewing the woman since not all the details are recorded in health passports.
2. Assessment of the current health status of mother and baby and if any danger signs/illnesses are discovered, they are referred to the health centre.
3. Provide health education and counselling on danger signs and family planning.

The details and findings of the activities conducted during antenatal and postnatal household visits are recorded on CBMNC register forms.

Two kinds of reports are submitted by HSAs to their supervisors: a CBMNC register form containing client-level data and a monthly reporting form containing aggregated data for the catchment area. The CBMNC register forms are reviewed then forwarded to the district programme offices where the data is entered into a Microsoft Access database application and different types of reports are produced. On the other hand, the submitted monthly reports are compiled by the supervisor to produce a report for the whole facility and this is then submitted to the district programme coordinator. It was noted that availability of reporting forms to the HSAs was usually a problem and requests for stationary (e.g. reporting forms) were at times communicated by the HSAs to their supervisors using mobile phones.

In addition to these activities, the HSAs follow-up on the clients they refer to the health centre in order to make sure the clients have gone to the health centre. This follow-up is done by asking the nurse at the health centre or by checking the health centre service registers. Alternatively, the HSA may also visit the client again after several days to check whether they actually went to the health centre.

5.3 Monitoring the Antenatal and Delivery Service Provision using Village Health Registers

The HSAs are required to capture demographic and health information of each individual in their catchment areas as a way of monitoring the implementation of the Essential Health Package (EHP) at household level.

Village Health Registers (VHR) are designed to fulfil this purpose and the details recorded include household demographic information and antenatal care and delivery, among others. These details are obtained from health passports and interviewing individuals.

5.4 Provision of Maternal Health Education and Counselling

The HSAs provide education and counselling on maternal health issues to the community through community gatherings and outreach clinics. The community sensitisations gatherings are sometimes conducted based on information from health centres. For instance, one nurse explained that they were getting cases of women delivering before arrival at the health centre from a particular area and therefore informed the HSA of that area, who then conducted a sensitisation campaign.
6 PROSPECTS ON USING M-HEALTH APPLICATIONS

The findings in section 5 indicate that HSAs are using mobile phones for communicating with their supervisors and voice phone calls are the most common use of the mobile phones. This is similar to cases presented in literature (Mechael et al., 2010;Mechael, 2005;Manda, 2009). In some health centres, the FrontlineSMS platform is being used to request for follow-ups and provide feedback on the follow-up cases thereby improving communication among the health workers. This is also similar to other studies presented in literature.

However, based on the activities of the HSAs and the associated information requirements, we examine the potential areas in which Electronic Health Records (EHR) and m-health applications could be used in tandem to support the information and communication needs of the HSAs.

6.1 Shared Access to Healthcare Records

The findings indicate the HSAs require information on healthcare provided at health centres and this information is currently obtained from health centre staff, service registers and health passports. This demonstrates the need for shared access to the health records of clients and this can be achieved through implementing an EHR system that is accessible through mobile technology to CHWs as implemented in other projects presented in the literature (UnitedNations, 2007).

The HSAs also require feedback on the clients they refer to health centres and this is currently obtained by asking the nurse at the health centre, or checking the service registers or visiting the client again. All this is time-consuming and having an EHR/mobile health application that enables the HSA to follow-up on a client’s health record would be beneficial in saving time on the follow-up.

Additionally, some new clients are identified by the HSAs in the community and then referred to the health centre for healthcare services. With an EHR and a mobile application, the HSAs would be able to register new clients and refer them to the health centres electronically as is done using the CommCare application.

6.2 Data Collection and Guiding Healthcare Protocol

The findings indicate that data is collected on the condition of the women and/or their newborn babies in order to assist in the early identification of danger signs. This client-level data is then sent for data entry into a computer database at the district level which results in a bulk of forms needing to be entered at the district level. With a mobile-based health application, the HSAs would be able to capture the data directly to an EHR system thereby improving timeliness and availability of the data. Additionally, this would increase the access to information on deliveries occurring at home or by TBAs thereby enabling health centre staff to monitor births taking place within the community.

Furthermore, the research discovered that HSAs faced challenges in the assessment of clients which resulted in clients wrongly diagnosed as having danger signs and this can be attributed to the fact that the HSAs have a non-medical background and are new to maternal and neonatal healthcare. Thus, with an application that guides the health worker in the assessment of clients, as is implemented in CommCare, the accuracy on the assessment (and data) would be improved. This has been demonstrated in other applications such as the implementation of the e-IMCI in Tanzania (DeRenzi et al., 2008) and (Mechael and Dodowa Health Research Centre, 2009) advocate for such an application.

6.3 Providing Notification on Deliveries

The HSA needs to be informed when a delivery occurs and the woman has been discharged. However, the current mechanisms for obtaining this information are unreliable and chances are the HSA can go for days without knowing or being informed about the birth especially with the fact that one HSA’s catchment area spans over several villages. Thus to ensure the HSA is informed on time, getting updates from the EHR system when a birth/delivery occurs at the health facility would ensure the HSAs are immediately informed and therefore, can schedule the necessary postnatal visit.

6.4 Providing Follow-up Requests

The health centre nurses use the HSAs to follow-up on certain clients and this requires that the nurse should identify the clients, identify the right HSAs and then communicate the details of the clients needing follow-up to the HSAs. The findings, however, indicate that due to high workload and low staffing levels in health centres, the nurses are not able to compile such information hence resulting in
poor follow-up service. With an EHR system that can automatically identify clients needing follow-up, and incorporates mapping of clients to appropriate HSAs based on their residential addresses, the EHR system would enable automated requests to be sent to the HSAs, thereby relieving the nurses of this cumbersome task.

6.5 Overall Design of EHR / M-health System

In essence, the proposed overall setup of the system, represented in Figure 1 below, is to have an Electronic Health Record system implemented on a server located at the health centre which the HSA is associated with. The EHR system will be accessible to local health workers at the health centre using workstations connected to the server on a LAN. The Server will have a GPRS modem to enable remote access to the health records by HSAs using a mobile-based application.

Figure 1: Overall design of the EHR/m-health system.

7 CONCLUSIONS

Adaptation of mobile technology in the HIS in developing countries is in the infant stages however promising results have been identified in different contexts showing improvements in health care delivery (Dimagi; Manda, 2009; United Nations, 2007). Through a detailed analysis of the current activities of Community Health Workers, the findings have indicated potential benefits of using mobile technology coupled with EHRs in improving delivery of maternal and neonatal health at the community level in Malawi.

Thus, the next stage of this ongoing research is the implementation of the EHR/mobile applications. The study will continue to explore existing systems such as CommCare and MoTECH with the aim of building on these already existing infrastructures and collaborating with other organisations implementing similar interventions.

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Appendix 2: Paper 2

A SCRUTINITY OF THE INTEGRATION STATUS AND STANDARDIZATION PROCESS OF ELECTRONIC MEDICAL RECORD SYSTEMS IN MALAWI

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Abstract: Achieving integration remains a challenge in many developed countries partly attributed to the presence of many different EMR systems which makes standardization and achieving interoperability a difficult and complex undertaking. Unfortunately, there is a lack of literature on whether and how developing countries in Africa are addressing issues related to integration of EMRs in their HIS agendas. A study was therefore conducted to assess the integration status, efforts and strategies in the implementation of EMR systems in Malawi in order to identify integration strategies and processes appropriate for the Malawian context. Thus, this paper presents the integration status and standardization efforts in Malawi and makes recommendations on how to progress towards standardization.

Keywords: Electronic Medical Record systems, integration, standards, Malawi.
A SCRUTINY OF THE INTEGRATION STATUS AND STANDARDIZATION PROCESS OF ELECTRONIC MEDICAL RECORD SYSTEMS IN MALAWI

1. INTRODUCTION

Throughout time paper-based medical record systems have proven to become more and more inefficient and are continuously failing to meet the care provider’s needs (Kalogriopoulos, Baran, Nimunkar, & Webster, 2009). In particular, the use of paper-based systems combined with challenges caused by the human resource crisis in most developing countries, have resulted in limited availability of reliable healthcare data. Hence, Electronic Medical Record (EMR) systems are being implemented in hospitals in developing countries in efforts to improve the accuracy, availability, completeness and timeliness of healthcare data (Chetley, 2006; Douglas, 2009; WHO, 2006; WITSA, 2006).

In the western world, the increased adoption of EMRs by different healthcare service providers has resulted in a large pool of independent EMRs within the healthcare systems (Brailer, 2005). Unfortunately, this has resulted in patients’ medical information being fragmented in different EMR systems as patients obtain health services from different healthcare service providers. In turn, this fragmentation poses a challenge in continuity of patient care by the different service providers. Thus, there is need for EMRs to be integrated to enable sharing and exchanging of patient data to ensure continuity of care (Ellingsen & Monteiro, 2008) and Brailer (2005) warns that without integration, EMR adoption will further strengthen the information silos that exist in existing paper-based medical files. In addition, the collaborating nature of healthcare work between different types of healthcare service e.g. clinical, radiology ward, pharmacy etc., emphasizes the central need for integration and data exchange between EMRs and other information systems (IS) (Aanestad, Grisot, & Nilsson, 2002).

It is clear that many studies that have analyzed EMR integration in developed countries acknowledge the complexities associated with the process (Arnold, Wagner, Hyatt, & Klein, 2007; Brailer, 2005; Ellingsen & Monteiro, 2008; Grimson, Grimson, & Hasselbring, 2000; Hanseth, Jacucci, Grisot, & Aanestad, 2007). The challenges are partly attributed to the presence of many EMR systems and vendors and other stakeholders which makes standardization and achieving interoperability a difficult and complex undertaking. However, studies related to EMR implementations in developing countries of Africa have mainly focused on identifying how EMRs can be implemented and used to improve healthcare service delivery in independent hospital settings (Douglas, 2009; Fraser, et al., 2005; Rotich, et al., 2003) . However, in order to avoid fragmentation of patients’ medical records caused by independent EMR system implementation, we believe there is need to address the integration requirements as the EMRs continue to be implemented in these developing countries. We argue that if EMR integration strategies and plans are delayed, achieving integration at a later stage will be more complicated and costly learning from the experiences of the developed world. Unfortunately, there is a lack of literature on whether and how developing countries in Africa are addressing issues related to integration of EMRs in their HIS agendas.

Therefore, in this paper, we present an assessment of the EMR integration status, efforts and strategies in Malawi, a developing country in Sub-Saharan Africa, with the intent of contributing to the literature on how EMR integration and standards development is unfolding in developing country contexts. Since EMR systems also interact with other IS, related information systems will also be included in this study.
Furthermore, this paper intends to provide recommendations on integration strategies and processes appropriate for the Malawian context that would inform government and various stakeholders concerned with the processes.

To achieve these objectives, the study set to answer the following research questions:

1. What EMRs have been implemented in Malawi?
2. What is the status of integration of EMRs in the country?
3. What strategies and processes are in place to ensure integration of EMRs?
4. What integration approach is required/appropriate for the Malawian context?

2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1. IS Integration

Integration is an ambiguous concept which has been interpreted in various ways leading to different approaches for implementation (Ellingsen & Monteiro, 2008). Previously, integration in IS has been predominantly conceptualized as a technical challenge, involving assembling of hardware, software and having a software bridge to bring together diverse elements (Zaitun, Mashkuri, & Wood-Harper, 2000). Hasselbring (2000) describe IS integration as focusing on three dimensions:

1. **Distribution** focuses on hiding the geographical distribution of systems. This can be achieved by using middleware components, which provide solutions for the technological interconnection of distributed systems. The aim is to make common data and facilities accessible to applications through standard interfaces thereby facilitating the management of the information common to the whole organization (Grimson, et al., 2000).

2. **Heterogeneity** is concerned with hiding the differences in hardware platforms, operating systems, database management systems, programming languages, programming and data models as well as the differences in understanding and modeling of the same real-world concepts (Hasselbring, 2000). For instance, information can be exchanged through interface engines via standardized messages (Grimson, et al., 2000).

3. **Autonomy** is focused on the extent to which the systems are independent. This can be achieved by using standard messaging as well as data warehousing whereby data from individual systems is integrated and homogenized in a single repository, the data warehouse (Grimson, et al., 2000). However, data warehousing is that it is not designed to support operational functions therefore the data in the individual IS is duplicated in the warehouse.

However, Chilundo & Aanestad (2005) explain that integration is not only a technical issue but also a social issue which requires that multiple institutional influences and different, possibly competing, rationalities should be aligned. Thus, a socio-technical approach towards integration is advocated for.

2.2. Integration of EMR systems: Approaches and Challenges

In the developed world, the approaches for integrating EMRs within the healthcare systems have evolved as the underlying objectives for pursuing the integration also evolved (Ellingsen & Monteiro, 2008).

Safran & Perreault (2001) indicate that most early attempts to achieve integration within hospitals adopted the philosophy that a single comprehensive central system could best meet the information needs of the healthcare organization. The focus here was to eliminate heterogeneity caused by different technologies. Hence, in this approach, implementing a standard software
system is seen as the means for achieving integration within the organization and this can be viewed as some kind of tight integration (Aanestad, et al., 2005). However, the main challenge with this approach is the inability of the system to accommodate the diverse needs of individual application areas. For instance, Hanseth, et al. (2007) show how attempts to implement one integrated EMR that replaced different clinical IS failed as it was impossible to include functions of all systems into the integrated EMR. A similar approach aimed at integrating EMRs between a group of hospitals through implementation of a common standard system in all the hospitals faced a similar challenge to accommodate the different work routines across the hospitals (Hanseth, et al. 2007). Thus, in the end, these (tight) integration efforts led to even more fragmentation.

With such unsuccessful attempts in achieving tight integration, an alternative approach adopted was the implementation of modular systems whereby different software application modules carry out specific tasks and a common framework defines the interfaces that allow data to be shared among the modules (Safran and Perreault 2001). Thus, this approach leans towards some form of loose integration whereby enabling interoperability of the different EMR systems is the key to achieving integration.

One approach for achieving interoperability is through the use of a gateway which is defined as a link between different elements (Hanseth, 2001). These gateways are a means to enable heterogeneity and autonomy; however, this solution is only appropriate at small scale e.g. when looking at a few systems within a hospital or between two hospitals and is unworkable when looking at a number of systems (Grimson, et al., 2000; Hammond & Cimino, 2001). Alternatively, interoperability at a large scale can be achieved through the use of standards such as the HL7, DICOM, and ISO/TR 18307 (Begoyan, 2007). However, the challenge is that the standards are not very stable as they evolve and change in parallel with the systems content and structure due to change in technology (ibid.). In addition, each standard has specific focus, for example HL7 is concerned with data exchange whilst ISO is concerned with content and structure, yet there is no consistency and coherence (ibid.).

Other than integrating into a single system or having different interoperable systems; another integration approach is to use a single data warehouse where operational EMRs and other clinical IS are kept (Grimson, et al., 2000). This enables the data collected by different systems over time to be mirrored in a central repository. Thus, the hospital systems maintain their autonomy and heterogeneity but must conform to set standards. However, the challenge with this approach is that data warehouses are not meant to support operational functions, and if they become operational systems, keeping data that is replicated consistent is a challenge (ibid.).

Thus, we see that each of the approaches above has its own limitations: a single system does not accommodate diverse needs of individual application areas; interoperability using gateways requires high engineering support and is not scalable whilst available interoperability standards are not stable; the data warehouse approach introduces duplication and in some cases, inconsistencies. Thus, the underlying objectives and dimensions which the integration intends to address play a crucial role in choosing the integration approach.

2.3. Development of Standards

Achieving integration of various heterogeneous and autonomous systems requires different types of standards to which the systems must conform to and according to Conrick, Walker, Scott, & Frean (2006), these standards can be categorized in four main areas as follows:

4. **System standards** which are required to achieve interoperability, integration performance and availability.

5. **Vocabulary standards** which are required for information management and meaningful collection, exchange storage and re-use of clinical data. This includes standards on data description and structure (i.e. nomenclature, classifications and terminologies)
6. **Messaging Standards** which are required to establish the format and sequence of data during transmission.

7. **Security standards** which are required to identify the practices necessary to maintain confidentiality, integrity and appropriate availability of health information.

In addition, Hammond & Cimino (2001) highlight that standardized identifiers for individuals (i.e. patients), healthcare providers, health plans and employers are pre-requisites for ensuring that such participants can be recognized across systems. Thus, standardized solutions are required for issuing identifiers, maintaining databases of identifying information, and authorizing access to such information *(ibid.)*.

According to Hammond & Cimino (2001), there are four ways in which a standard can be produced:

1. Ad hoc method whereby a group of interested people/organizations agree on a standard specification which is accepted through mutual agreement of the participating groups.
2. De facto method whereby a single vendor controls a large proportion of the market to make its product a standard.
3. Government-mandate method whereby a government agency creates a standard and legislates its use.
4. Consensus method in which a group of volunteers representing interested parties work in an open process to create a standard.

Furthermore, Hammond & Cimino (2001) indicate the process of creating a standard goes through the following stages:

1. Identification of the need for the standard.
2. Conceptualization which involves defining characteristics of the standard.
3. Discussion stage involves defining content, critical issues, pros and cons and a time line.
4. Early implementation which requires maintenance and promulgation of the standard to ensure availability and continued value of the standard.
5. Conformance during which agreements are made on compliance with the standard.
6. Certification whereby a neutral body certifies that a product complies and conforms to the standard.

However, Hammond and Cimino (2001) are not explicit and do not provide details on whether and how the process differs in each stage for the different methods. For instance, in our view, the de facto method is not expected to go through the stages as described above.

### 3. RESEARCH CONTEXT AND APPROACH

#### 3.1. Research Context- The Malawi Health System

The research was conducted in Malawi, a developing country in Sub-Saharan Africa. The country is administratively divided into three regions namely North, South and Central and these regions are further divided into 28 districts countrywide.

The Ministry of Health (MoH) has overall responsibility for developing policies, planning strategies and programmes, and ensuring that all providers follow the national policies and standards so that quality health services are provided to the population. The ministry has several technical departments: Preventive Health, Clinical, Nursing, Health technical, Finance and Administration; and Health Services Planning. One of the divisions under Health Service Planning is the Central Monitoring and Evaluation Division (CMED) which is responsible for the
management of the country’s Health Information Systems and for the oversight of all monitoring and evaluation activities carried out in the health sector in Malawi (CMED, 2009).

There are three main agencies providing healthcare services in the country: the Ministry of Health providing 60% of health service, the Christian Health Association of Malawi (CHAM) provides 37% and the Ministry of Local Government provides 1%. In addition, there is a small private-for-profit health sector but this is limited to the urban areas (MoH, 2007).

There are three levels in the health system i.e. primary level comprising of health centres, health posts, dispensaries, and rural hospitals; second level made up of district and CHAM hospitals; the tertiary level consisting of the central hospitals and one private hospital with specialist services (MoH, 2007).

3.2. Research Approach
This study adopted an interpretive qualitative case study approach in its assessment of the integration status and strategies in Malawi and data was collected through interviews, document review, workshop participation, informal discussions and observations.

Semi-structured interviews were conducted to different professionals at health facilities to obtain data on existing electronic systems and their associated mechanisms for sharing and exchanging data. 8 individuals working in five different health hospitals were interviewed (4 in Lilongwe district and 1 in Mzimba district). The hospitals included Government-owned central hospitals and CHAM hospitals which were known to have EMRs through the authors’ involvement in HIS-related forums such as the National Data Standards Workshop in November 2008 (two authors attended). In addition, data from other hospitals was obtained through the authors’ participation; in particular, one of the authors is involved in EMR implementation projects in various hospitals within the country, thus, in this case “researcher as employee” method was used (Easterby-Smith, Thorpe, & Lowe, 1991).

Documents reviewed included proceedings of relevant workshops and meetings related to HIS standards development.

Data was also obtained through the authors’ participation in meetings and HIS related projects within Malawi. In particular, three of the authors are part of a national health data standards taskforce that was established in 2008 and have been attending meetings of the taskforce.

The data analysis was guided by the research questions whereby themes/focus areas were identified within each question. The data collected was analyzed by coding and authors' interpretation techniques resulting in the data being organized according to the themes identified of which some were presented in tabular form as demonstrated in the findings section below.

4. RESEARCH FINDINGS

4.1. Electronic Health Information Systems in Malawi
The research identified different electronic IS implemented within the healthcare sector (see table 1 below). Most of these implementations are donor-funded and research-driven. Due to donor interest mostly on HIV/AIDS, most EMR systems are geared towards this area. However, the study discovered that new EMR systems are also being developed, some of which are focused on other health areas such as Maternal and Child Health. Some of the existing systems have been scaled to other sites and the systems developed by Baobab Health Trust, a Malawian NGO, are the most widely scaled thereby, making Baobab a leader in EMR system implementation.
<table>
<thead>
<tr>
<th>Electronic HIS</th>
<th>Purpose</th>
<th>Developer &amp; Underlying Technology</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Registration</strong></td>
<td>Register out-patients and gather data on patients’ daily attendance</td>
<td>– Developed by Baobab Health Trust&lt;br&gt;– Underlying Technology&lt;br&gt;  o Ubuntu&lt;br&gt;  o MySQL&lt;br&gt;  o Ruby-on-rails + other JAVA based development tools</td>
<td>– Central hospitals: KCH, QECH &amp; ZCH&lt;br&gt;– District hospitals: Bwaila, Dedza, Kasungu, Ntcheu, Machinga &amp; Mangochi&lt;br&gt;– 2 Rural health centres: Mbang’ombe and Ngoni&lt;br&gt;– ART clinics: Lighthouse at KCH, Martin Preuss Centre at Bwaila</td>
</tr>
<tr>
<td><strong>Out-Patients Diagnosis (OPD)</strong></td>
<td>Captures patient diagnosis information</td>
<td>– Baobab Health Trust&lt;br&gt;– Underlying technology is the same as Patient Registration system</td>
<td>– Central hospitals: KCH, QECH &amp; ZCH&lt;br&gt;– District hospitals: Dedza, Kasungu, Ntcheu, Machinga &amp; Mangochi&lt;br&gt;– 2 Rural health centres: Mbang’ombe and Ngoni</td>
</tr>
<tr>
<td><strong>Radiology System</strong></td>
<td>Capture data on patient’s requested examinations, results, and resources used.</td>
<td>– Baobab Health Trust</td>
<td>– Central Hospital: KCH</td>
</tr>
<tr>
<td><strong>Maternity Registration System</strong></td>
<td>Register and collect data on maternity patients</td>
<td>– Baobab Health Trust</td>
<td>– Bwaila Hospital</td>
</tr>
<tr>
<td><strong>Computer Radiography system</strong></td>
<td>Capture digital X-ray images which are sent to Belgium for consultation.</td>
<td>– Belgium-based organization</td>
<td>– Kamuzu Central Hospital</td>
</tr>
<tr>
<td><strong>District Health Information System (DHIS)</strong></td>
<td>Capture and process aggregate data for health facilities.</td>
<td>– Developed by HISP&lt;br&gt;– Underlying Technology&lt;br&gt;  o MS Windows&lt;br&gt;  o MS Access</td>
<td>– All Central hospitals and District Health Offices in Malawi</td>
</tr>
<tr>
<td><strong>Lab Information System</strong></td>
<td>Captures and manages patients’ Lab data (tests, results, reports, etc)</td>
<td>– University of North Carolina (Short et al.) – USA&lt;br&gt;– Underlying Technology&lt;br&gt;  o MS Windows</td>
<td>– Kamuzu Central Hospital</td>
</tr>
<tr>
<td></td>
<td>Captures and manages patients’ Lab data (tests, results, reports, etc)</td>
<td>– Pre-Link and Liverpool-Welcome Trust</td>
<td>– Queen Elizabeth Central Hospital</td>
</tr>
<tr>
<td><strong>Lab Database Management System</strong></td>
<td>Tracking specimens</td>
<td>– UNC- USA</td>
<td>– Kamuzu Central Hospital</td>
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<tr>
<td><strong>E-data system</strong></td>
<td>Manage clients data</td>
<td>– UNC- USA</td>
<td>– Kamuzu Central Hospital</td>
</tr>
<tr>
<td><strong>Data Fax</strong></td>
<td>Scan and manage case forms.</td>
<td>– UNC- USA</td>
<td>– Kamuzu Central Hospital</td>
</tr>
<tr>
<td><strong>Pediatrics ART EMR</strong></td>
<td>Captures and manages patient data and M&amp;E.</td>
<td>– Baylor Children’s Foundation</td>
<td>– Kamuzu Central Hospital</td>
</tr>
<tr>
<td><strong>Baobab ART (BART)</strong></td>
<td>Captures and manages ART patients data on</td>
<td>– Baobab Health Trust</td>
<td>– KCH Lighthouse &amp; Bwaila Martin Press Centre</td>
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<td></td>
<td>Treatment and M&amp;E</td>
<td>District hospitals: Dedza, Kasungu, Ntcheu, Machinga &amp; Mangochi</td>
<td>St. Gabriel's Hospital</td>
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<tr>
<td>SPINE</td>
<td>Capture in-patients diagnosis data in wards</td>
<td>Baobab Health Trust</td>
<td>Queen Elizabeth Central Hospital</td>
</tr>
<tr>
<td>Diabetes Mellitus and Hypertension (DMHT)</td>
<td>Collect and manage data of diabetes patients</td>
<td>Baobab Health Trust</td>
<td>Queen Elizabeth Central Hospital</td>
</tr>
<tr>
<td>Rainbow/ TESTMART</td>
<td>Captures and manages ART patients data on treatment and M&amp;E</td>
<td>Developed by Luke International Norway (LIN)- Malawi</td>
<td>Mzuzu Central Hospital</td>
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<td></td>
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<td>Underlying Technology</td>
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<td>o Delphi</td>
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<tr>
<td>Lab Information Management System</td>
<td>Capture and manage Lab data (tests, results, reports, etc)</td>
<td>LIN</td>
<td>Mzuzu Central Hospital</td>
</tr>
<tr>
<td>Drug Store System</td>
<td>Tracking, monitoring and ordering drug supplies</td>
<td>LIN</td>
<td>Mzuzu Central Hospital</td>
</tr>
<tr>
<td>Afyapro</td>
<td>Patient registration, billing, diagnosis, admissions, discharges, and lab information management,</td>
<td>NPK Technologies</td>
<td>Nkhoma Mission Hospital, Lilongwe</td>
</tr>
<tr>
<td>MS Excel</td>
<td>Captures patient data and health statistics from the hospital departments</td>
<td>MS Windows</td>
<td>Daeyang Korean Mission Hospital – Lilongwe</td>
</tr>
<tr>
<td>FUSHIA</td>
<td>Captures and manages ART patient’s data on treatment, TB and nutrition and M&amp;E</td>
<td>MSF</td>
<td>2 District Hospitals: Thyolo and Chiradzulu</td>
</tr>
</tbody>
</table>

**Table 1: Existing Electronic Health Information Systems in Malawi**

### 4.2. Integration Status: data exchange between/across systems

The study discovered that there was indeed a need for data to be shared and exchanged between different systems especially those operating within a particular health facility e.g. at the central hospitals. For instance, one health professional providing ART to children born to HIV positive women explained:

> “It would be important for us to access the data from the [Maternity] system in order to obtain details on which ART treatment was given to the mother during pregnancy so as to provide the appropriate treatment to the exposed child”

In addition, the study also discovered that it was necessary for different health facilities to exchange patient data especially where there was collaboration and support in provision of specific services. For instance, it was indicated that there was need to exchange data between Partners in Hope, Daeyang hospital and Nkhoma hospital which are all CHAM hospitals located in Lilongwe district.
Several mechanisms were indicated as being used to enable the exchange of data between the systems and this is summarized in table 2 below; however, the most common was the use of paper-based records between the health providers. For example, examination results from the Radiology department at Kamuzu Central Hospital (KCH) were printed out from the electronic system and sent to relevant departments in paper format. Nevertheless, some of the existing electronic systems were able to exchange and share data in cases where the systems were developed by the same provider, e.g. Baobab, LIN and UNC. Furthermore, LIN have a data export module as part of their systems that is able to export data to HL7 format and thus other systems following this standard can import this data; however, this import functionality is not implemented in any of the systems yet. Hence, in general, exchange of data between electronic systems was limited and paper-based forms/tools act as gateways for sharing data between the different systems.

Furthermore, aggregated data from different systems, both electronic and paper-based, was made available to Ministry of Health (national level) and District Health Offices (district level) in paper format.

<table>
<thead>
<tr>
<th>Electronic HIS</th>
<th>Data Exchange mechanisms within a health facility</th>
<th>Data Exchange with other health facilities /organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baobab Systems</td>
<td>- Print-outs and paper-based forms</td>
<td>- Print-outs and paper-based forms</td>
</tr>
<tr>
<td></td>
<td>- Centralized Patient registration system for the different Baobab systems (at QECH)</td>
<td></td>
</tr>
<tr>
<td>Computer Radiography system</td>
<td>- Unknown</td>
<td>- Emailing of digital images</td>
</tr>
<tr>
<td>UNC systems</td>
<td>- All UNC systems are integrated and data can be accessed through Patient Identifier by different types of health workers at UNC.</td>
<td>- Print-outs and paper-based forms</td>
</tr>
<tr>
<td></td>
<td>- Print-outs and paper-based forms</td>
<td>- Centralized system accessible to other health facilities through VPN connection to their network at KCH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Scanning of case files and sharing through email</td>
</tr>
<tr>
<td>Pediatrics ART EMR</td>
<td>- Print-outs/ paper-based forms</td>
<td>- Print-outs and paper-based forms</td>
</tr>
<tr>
<td>LIN systems</td>
<td>- Paper-based print-outs and forms</td>
<td>- Paper-based print-outs and forms XML format (HL7 standard)</td>
</tr>
<tr>
<td></td>
<td>- Data export module</td>
<td>- Spreadsheets or Rich Text File.</td>
</tr>
<tr>
<td>Afyapro</td>
<td>- Paper-based print-outs and forms</td>
<td>- Paper-based print-outs and forms Import and Export of reports, tables or actual database</td>
</tr>
<tr>
<td></td>
<td>- Import and Export of reports, tables or actual database</td>
<td></td>
</tr>
<tr>
<td>MS Excel</td>
<td>- Spreadsheet sharing</td>
<td>- Spreadsheet sharing</td>
</tr>
<tr>
<td></td>
<td>- Paper-based forms</td>
<td>- Paper-based forms</td>
</tr>
<tr>
<td>FUSHIA</td>
<td>- Unknown</td>
<td>- Unknown</td>
</tr>
</tbody>
</table>
4.3. Existing Integration Efforts

The study identified several efforts to integrate the existing electronic systems at hospital level, between/across hospitals, and between different levels of the health system.

At the hospital level, the study discovered that some stakeholders had seen the need to integrate their systems with that of other service providers. For instance, Kamuzu Central Hospital was planning to have its Computer Radiography system (digital x-ray, picture archiving and communication system) linked to the Baobab systems in order to enable other departments in the hospital to view patient’s examination results electronically. At Queen Elizabeth Central Hospital, Welcome Trust was seeking to have their Lab system, linked to Baobab systems, to enable electronic requesting for lab tests and retrieval of lab results for patients. However, even though these various stakeholders had expressed their interests in integration, there was no evidence of concrete plans or activities towards the integration of these systems.

Luke International Norway (LIN) and Baobab had also been discussing on how to enable exchange of data between their systems and the development of the module that is able to export data to HL7 format is a step forward towards this goal. Work still remains to develop the corresponding import module.

At a national/sector level, the efforts to have an integrated health information system were strengthened through a National Health Data Standards workshop held in 2008 that was organized by MoH (CMED) in partnership with CDC and the WHO. Participants of the workshop were from various organizations within the private and public health sector that were involved in health service provision, financing, monitoring and HIS software providers which included international partners/donors. During the workshop, priority areas, including standards, required for the Malawi Health Information System were identified and the following were some of the areas/activities that were considered of high priority:

1. Implementation of a national Patient Identification Scheme for the entire health system
2. Implementation of a Facility Identification System for generating and maintaining a complete, accurate list of health facilities with correct naming and unique identifiers.
3. Implementation of a centralized data repository (i.e. data warehouse) that would initially be able to handle patient level data along with aggregate data.
4. Development of standards for messaging of patient information between different systems.
5. Connectivity

As a result of this workshop, a national health data standards task force was established, consisting of different stakeholders within the health sector, with the overall responsibility to facilitate the development of required standards for the HIS. The Task Force is part of the SWAP Governance Structure, nested under the Monitoring and Evaluation Technical Working Group (M&E TWG). The taskforce was further divided into three subgroups: the Data subgroup, Architecture subgroup, and Security subgroup - the data subgroup being responsible for ensuring that data being collected have uniform definitions; and each health facility has a unique identifier among other things. The architecture subgroup was given the responsibility of designing and implementation of a national data warehouse using the data identified by the data subgroup and the security subgroup was responsible for defining security and identification schemes.

The taskforce has been holding regular meetings (almost every three months) since its establishment in 2008 and thus this has provided a forum whereby stakeholders have shared their ongoing and planned activities in relation to HIS, share experiences and various collaborations have emerged through these meetings. However, in one of the meetings (held almost one and a
half years since the taskforce establishment), it was noted that the subgroups had not been working as they had been expected due to lack of clear Terms of Reference (TOR) and tasks defined for the sub-groups. Thus, the framework for the taskforce was defined (see figure 1) and TORs formulated for each group. Each group was then required to define its own objectives, specific activities, outputs and desired outcomes. In addition, the taskforce has been working towards formulating a work plan to guide the activities of the taskforce and the subgroups.

![Data Standards Task Force Framework](image)

**Figure 1. Health Data Standards TaskForce (Adapted from BaobabHealthTrust, 2010)**

Even though, no standards have been produced yet by the taskforce, several activities are underway that are geared to the development of standards for the HIS. One of the main activities is the ongoing development of a national patient identification system which is at a piloting stage. The development of the national patient identification system was led by a group of the taskforce members who developed the requirements for an identification system. This team consisted of three members who were from the following organizations: MOH, CDC and Baobab. These requirements were then shared to all members of the taskforce for inputs and feedback. Later on, Baobab, based on their experience in similar systems development, led the formulation of the technical specifications/requirements of the identification system and developed the system that is being piloted in Zomba district in Malawi in collaboration with other stakeholders. Throughout this process, other members of the taskforce were constantly consulted through taskforce meetings and provided feedback on the identification system.

In addition to the patient ID system, a group of members of the taskforce are currently working towards developing an integrated concept dictionary that would facilitate standardization of the medical vocabulary across different systems within the health sector. This activity was initiated by two organizations (Baobab and Partners in Health-Neno) that were working in partnership in the implementation of EMRs based on the OpenMRS (data model). The development of the dictionary
is currently at a standstill awaiting a consultative meeting with other stakeholders particularly clinical health professionals.

Furthermore, in-line with the taskforce’s priority to establish a central repository, the application DHIS2, which is a web-based free and open source application recommended by WHO HMN, is being piloted by the Ministry of Health, in collaboration with College of Medicine, as a data warehouse that would integrate aggregated data from different electronic and paper-based systems within the health sector at district and national levels.

5. ANALYSIS AND DISCUSSION

5.1. EMR Integration Status, Efforts and Approach

The findings indicate that different EMR systems have been developed by different health software developing organizations using different underlying technologies. Some of the software developing organizations have more than one system e.g. Baobab has EMRs for OPD, ART, Maternity, Diabetes, Radiology. Some of the systems have also been implemented in more than one site thereby resulting in geographical distribution of the systems.

This implies that within our context, all three dimensions of integration as defined by Hasselbring (2000) are required. In particular, the systems that are geographically dispersed need to exchange information if a patient moves from one place to the other. This is currently not feasible for all the systems and therefore integration strategies have to address distribution of the systems.

The existing systems are heterogeneous mainly in two ways: 1) they are developed by different organizations, using different technologies and 2) they are addressing different healthcare areas. Thus, addressing heterogeneity implies that the different system from e.g. LIN and Baobab ART systems should be able to exchange data; and ART, OPD, and LAB systems should be able to exchange data. Currently systems that are able to exchange or share data are limited to those developed by the same organization, i.e. Baobab, LIN and UNC.

Autonomy of the systems within the healthcare system is also evident, for instance, the Radiology system and Computer Radiography system at KCH are being used independent of each other. This is common with systems that have been developed by different organizations, though the implementations are in the same hospital. Hence, autonomy is an issue that also has to be addressed.

In general, we see that efforts to achieve/incorporate integration in the implementation of various electronic patient-based systems in the health sector have been limited. Integrated systems that are able to exchange or share data are limited to systems developed by the same organization. This has been achieved through their modularized implementation of their systems resulting in loose integration. The modularity in the systems can be attributed to the limited availability of funding and the focus on specific health areas for the implementation projects.

The findings also reveal that different types of gateways are being used to enable exchange of data between the existing systems. Shaw, Mengiste, & Braa (2007) indicate that gateways could be paper-to-paper, paper-to-computer, or computer-to-computer. We see that computer-to-paper gateways are common as data from electronic systems is made available through paper print-outs. These print-outs then act as inputs to other electronic.

The findings also show that there are some organizations such as LIN, working towards a computer-to-computer gateway to enable export of data from one system to the other. The gateway is in form of a data export module within the systems that is able to export data to HL7 format. This requires that other systems should be able to import the data in these formats to their various systems. Hence, interoperability will be achieved through the use of the HL7 standard.

However, at a national level, a data warehouse has been adopted whereby the data from various EMRs implemented is expected to feed into a centralized database (warehouse) at a national level.
However, the details of this data warehouse architecture have not been defined yet and are part of the responsibility of the Architecture sub-group of the taskforce. As this process unfolds, challenges related to the networking infrastructure that would affect synchronization mechanisms will be of paramount importance.

Thus, we see that a combination of integration approaches are evident i.e. in practice, systems implementation is leaning towards interoperability whilst at a higher level data warehousing has been adopted.

5.2. The Development of Standards in Malawi

It is clear that the need for standards in the achievement of any integration and interoperability of EMRs within the health sector is well recognized in Malawi; hence the establishment of the Health Data Standards taskforce to facilitate the development of required standards. Among the required set of standards, standards for unique patient identification and hospital/facility identification have been given priority as they are central for integration to occur.

Through the establishment of the Health Data Standards taskforce it is clear that a consensus method has been adopted as defined by Hammond & Cimino (2001). However, looking at the actual process for the development of standards, progress made so far on the development of a patient identifier system was facilitated by few interested stakeholders who defined the requirements for the system. Similarly efforts to develop a concept dictionary were facilitated by members who were interested in the formulation of the standard. Therefore, this demonstrates evidence of the adhoc method within the taskforce. In addition, the overall framework of the taskforce provides for the establishment of adhoc committees.

The case also has demonstrated aspects of a de facto approach whereby, Baobab, as leaders within the local HIS software industry, are developing the software for a National Patient ID system based on their technologies, thus, in a way, their adopted technology e.g. the bar-code scanner/printer become part of the standard.

Therefore, from this case, we see that even though the overall approach is identified as a consensus method, analyzing the standards development process shows characteristics of other methods i.e. adhoc and de-facto are also evident. Thus it is not either one or the other but a combination of methods is at play.

Looking at the patient identification standard development process based on Hammond & Cimino (2001) staging, the identification of the need for the standard was done through a consensus at the data standards workshop as well as during the taskforce meetings. Discussions on the required characteristics of the system began through one of the taskforce meetings, however, it was agreed to hold a separate meeting where interested parties would continue discussions. This, in turn, resulted in a smaller group being formed that continued with the conceptualization and the discussion stages. As indicated in the findings, the outputs of each of the stages were shared with the whole taskforce thereby ensuring that taskforce members prove their input.

The case demonstrates one advantage of using the adhoc within this taskforce and that is - it is easier and faster to make progress towards development of the standards as the involved parties are more committed and have keen interest in the outcome as seen in the implementation of the patient ID system. On the other hand, the subgroups that were formulated have not been productive as expected due to lack of commitment probably facilitated by the lack of clearly defined activities and work plans. Hence, it is anticipated that the development of the taskforce and sub-group work plans that is underway will guide the groups in the development of the required standards.

Furthermore, the case of the development of the concept dictionary demonstrates the delays that are associated with the consensus building through consultative process especially when considering stakeholders that are not represented/part of the taskforce. Thus we recommend that...
there is a need to re-identify the different types of stakeholders that are essential in the standards development process and ensure they are part of the taskforce.

Since the taskforce is operating under the M&E TWG, it is expected that this group will be responsible for the approval/accrediting of proposed standards developed by the data standards taskforce. Once these standards are in place, it will be essential that a body is identified that monitors and certifies that systems comply and conform to these standards. We propose that this body should be under MOH, having the appropriate authority to monitor existing and new information systems and certify their compliance to the standards. This will require that the body consists of individuals with the appropriate skills/knowledge in the different types of health information standards.

6. **CONCLUSION**

This paper has clearly demonstrated that there are different players with their own EMRs in the health-sector in Malawi. It has shown that EMRs implemented at one health facility are unable to exchange patient data electronically; where they do it is typically from electronic to paper transfer of data (i.e. paper print out), which in some ways defeats the whole purpose of having an electronic system. Integration of distributed system is completely lacking and integration of heterogeneous systems is limited to those that are developed by the same organisation. Therefore, the findings re-enforce the need for a strategy for integration of EMRs in the Malawi health-sector sooner rather than later, because if the status quo continues it will be very costly as well as very cumbersome to achieve integration and interoperability of EMRs in the future. The foregoing literature has shown how difficult it is to undertake this process at a late stage.

The establishment of the National Data Standards taskforce is a positive adventure towards the integration of EMRs within the health sector and the Data Warehouse approach seems appropriate for the context in Malawi as it has the potential to address the dimensions of integration that are required. However, whether this approach is able to achieve this will depend on the design of the Data Warehouse architecture which remains undefined. We see that careful thought will have to be given to the infrastructure and synchronization mechanisms in order to address challenges associated with this data warehouse approach.

It has been noted that adopting a consensus approach in the development of standards is beneficial in ensuring that interests of various stakeholders are taken on board so that the standards address their needs. In the absence of clear objectives and plans for the Data Standards Taskforce, the adhoc approach to standards development within the taskforce has proven effective in making progress towards the development of standards as involved members had full commitment in the process. In addition, we see a de-facto standard in the making in form of the National Patient ID system. Thus this case shows how characteristics of different methods can unfold during the standards development process based on various factors.

Nevertheless, as a way forward for Malawi, we argue that once clear objectives have been defined for subgroups, the commitment of the individuals within the subgroups- which is largely based on their organisational interests- will be an important factor on the pace of development of the standards. Therefore, it is essential that commitment from members is affirmed.

We also recommend that an assessment of the required types of stakeholders needs to be done and the missing groups to be represented in the Data Standards Taskforce. Furthermore, there is need to establish clear procedures which will ensure that Ministry of Health is able to approve EMRs to be implemented in the country (including private and CHAM Hospitals) and thus, have the capability to monitor and certify compliance with the developed standards.
7. REFERENCES AND CITATIONS


CMED (2009). Central Monitoring and Evaluation Division Website Retrieved 1 September 2010


Appendix 3: Paper 3

Balancing Work Practices and Protocols in the Design of EMR Systems: The Case of Developing an EMR System for Antenatal Care Services in Malawi

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Abstract
Implementing ICTs in healthcare settings has proved to be very challenging such that progress towards widespread adoption and use of Electronic Medical Record (EMR) systems has been slow. The challenges of implementing these technologies have been described as complex, diverse, and locally situated. One of the challenging aspects of designing EMR systems is the need for inscribing standardised protocols whilst taking into account local work practices. Previous research has called for the need to balance work practices and protocols in the design of EMR systems. We present an attempt to balance the work practices and protocols in the development of an EMR system for antenatal care in a developing country, Malawi. This was done through implementing weak inscriptions of the protocols in some cases and strong inscriptions in other cases. The study highlights the important role that clients play in healthcare work and thus, influence the design of EMR systems.

Keywords: antenatal care, developing countries, EMR system design, inscriptions, protocols, work practices

1. Introduction
It is believed that Information and Communication Technologies have the potential to contribute to improved efficiency, access and quality of healthcare services with the Electronic Medical Record (EMR) as the central element (Chetley, 2006; Fitzpatrick and Ellingsen, 2012; Khan et al., 2012). The implementation and use of EMR systems has been explored in developed countries for more than three decades, but the progress has been slow such that there continues to be limited adoption and use of the systems in healthcare institutions (Boonstra and Broekhuis, 2010; Chaudhry et al., 2006; Sood et al., 2008). This indicates that successful design and implementation of EMR systems continues to be a challenging task (Chaudhry et al., 2006; Fitzpatrick and Ellingsen, 2012; Vikkelso, 2005). Some of the challenges inhibiting adoption and use of EMRs among health workers are attributed to the top-down approach of implementing EMRs (Berg, 1999a). Hence, a bottom-up approach to the development of EMR systems, which is more user-oriented, is advocated for (Berg, 1999a; Weiderhold and Shortliffe, 2001).

The bottom-up approach is particularly a central theme within Computer Supported Cooperative Work (CSCW) studies where focus is placed on understanding the nature and requirements of daily work practices as a starting point for designing any system (Fitzpatrick and Ellingsen, 2012; Schmidt and Bannon, 1992). Therefore a fundamental conviction is that the essence of work practices cannot be caught in pre-fixed workflows, clinical pathways, formal task descriptions, protocols, procedures or other formal methods (Berg, 1999a; Suchman, 1983). Thus, the use of such formal methods within EMR systems to bring structure and rationality to the work of healthcare professionals is highly criticized (Berg,
This is corroborated through several studies that have shown how too much structure jeopardizes the human side of medicine and nursing by distracting staff into data entry and standardized protocols, and putting additional burdens on healthcare personnel (Allen, 2012; Berg, 1999a; Greenhalgh et al., 2009). In most cases, these studies have been conducted in developed contexts and are dealing with highly qualified health professionals such as doctors and nurses. However, the situation presents differently when looking at the contexts of developing countries where qualified healthcare personnel are limited, knowledge levels are low among the existing care providers, and poor quality of care predominates.

The quality of healthcare services is particularly lacking in the public sector, which is normally the main provider of the services, and the poor quality is attributed to various factors including limited availability of qualified health personnel, medical drugs, supplies and equipment (Mueller et al., 2011). One area where delivery of high-quality care is lacking, especially in Sub-Saharan Africa, is Maternal health care as the region accounts for more than half of the maternal deaths in the world (United Nations, 2012). When looking specifically at the provision of Antenatal Care (ANC) services, there is a substantial quality gap in services as most women attending antenatal care do not receive the full range of evidence-based components during pregnancy (Kinney et al., 2010; Lungu et al., 2011). One of the challenges that contribute to the poor quality in the delivery of maternal health care services includes limited knowledge among health providers (Anatole et al., 2012; Mueller et al., 2011). Training and supervision of these providers is limited and therefore considered inadequate for ensuring delivery of high-quality care (Anatole et al., 2012).

Considering this situation, inscribing protocols in the design of EMR systems to provide decision support is appealing and a few cases have demonstrated potential benefits in improving quality of care in some developing countries (Castelnuovo et al., 2012; DeRenzi et al., 2008; Douglas et al., 2010). Furthermore, it has been indicated that inscribing protocols, for instance in the form of computerized reminders, have proved beneficial in preventive care settings by improving adherence to protocol-based care (Black et al., 2008; Chaudhry et al., 2006). Hence, it can be argued that in developing EMR systems for developing contexts, especially preventive care services such as antenatal care, the goal cannot only be to support the existing work practices but also to improve the quality of healthcare services by inscribing protocols. Although this is a common goal even for developed countries, the status of care services in developing countries certainly calls for considerable attention to quality of care as compared to what may be required in developed countries. This, in turn, results in the need to employ both top-down and bottom-up approaches in the development of the EMR systems.

Studies of EMR design conducted in developing countries have focused on identifying appropriate technical designs for EMR systems and objective quantitative evaluations of the impact of the systems on healthcare processes and the outcome on patient care. These studies have identified various design and implementation challenges such as poor electricity and ICT infrastructures, lack of back-up systems, limited health care budget, low staffing levels, high risk of theft, lack of local technical expertise to support the systems, and poor systems security leading to viruses (Douglas, 2009, Fraser et al., 2005, Sood et al., 2008). However, studies are lacking that analyse and discuss the EMR design process and the complexities of balancing the work practices and protocols in the context of developing countries (Fitzpatrick and Ellingsen, 2012). This paper aims to address this gap by presenting how an EMR system was designed for use in a rural health centre in Malawi, a developing country in Sub-Saharan Africa. We have adopted a socio-technical perspective to understand how EMR systems can be developed with considerations on both the existing work practices and the protocols defined by top management. Through this case, we analyse the work of balancing in the context of EMR systems design in a developing country setting and thereby
contribute to the understanding of how modest use of protocols can be achieved in the design of patient care IS, which, according to Fitzpatrick and Ellingsen (2012) still remains unclear.

The paper addresses the overall question: How do protocols and work practices influence the design of EMR systems in developing contexts? We answer this by looking at three specific questions from the case:

1. What are the discrepancies between protocols and work practices?
2. How are these discrepancies addressed in the development of the EMR system?
3. How do these discrepancies impact on the EMR system design?

Moving within these questions, the study presents the defined protocols, the existing work practices, the discrepancies between the two and how these were handled during the development process, and the outcome on the system design.

The rest of the paper is organized as follows. The next section presents previous work that has looked at the role of protocols and design of EMRs. The section also presents the concept of inscriptions which is important for analyzing this case. Section 3 describes the study context, Malawi, and the research method that was applied. The case of antenatal care services is then presented in section 4 focusing on the care protocols, work practices, the existing paper-based Health Information System, and the discrepancies between the work practices and protocols. Section 5 then presents the overall design principles of the EMR system and how the specific discrepancies were addressed in the EMR system design. These discrepancies and effect on the design of the EMR systems are then discussed in section 6. Lastly, section 7 summarizes the paper focusing on the three specific research questions.

2. RELATED WORK
This section presents previous work on the role of protocols within healthcare practice and the implications for the design of EMR systems, mainly building on the studies from Marc Berg. Lastly, we introduce the concept of inscription which we use to analyse the outcome of the design.

2.1 The Role of Protocols and Implications on EMR Design
Protocols can broadly be defined as a set of instructions to guide health personnel through a sequence of steps (Berg, 1997). Protocols are a form of procedural standard or best practice that describes good clinical reasoning in such a way that it becomes transferable across sites, assessable, and in accord with sound scientific principles (Berg, 1997; Timmermans and Berg, 2003). Essentially, the protocols standardize a set of practices, actors and situations (Timmermans and Berg, 1997). The term protocol is often used interchangeably with clinical guidelines and procedures, care processes or clinical pathways, and algorithms (Berg, 1997; Rycroft-Malone et al., 2009). For this study, we use the term protocol as a general term for the different types of formal methods.

Several arguments have been presented criticizing the use of protocols in healthcare. The first critique that Berg (1997) presents concerns that even if medical personnel are aware of the existence of protocols and use them, they are often circumvented, tinkered with and interpreted in many different ways. He argues that one of the problems with protocols is that they portray management of patient’s trajectory as constituted by a sequence of individual, formally rational decisions, whilst in practice, it is a social process characterized by the (re)construction of data in and through ongoing interactions between health care workers and patients and the intertwining of a decision with the context in which it is produced. Thus, a protocol may describe in great detail when to do what, but the continual popping up of practical contingencies such as time pressure, specific patient needs, and the availability of
diagnostic and therapeutic technologies exert greater urgency and therefore play a much larger role than the formal view assumes (Berg, 1997). Therefore, in practice there are different logics/rationalities in which considerations are weighed, and which rationality comes to the fore depends on the salient features of the situation at hand (Berg, 1997). The implication for the design of EMRs is that systems embodying a single rationale will often be put aside (ibid.). In other words, EMR systems should allow for multiple rationalities that requires flexibility in the EMR design.

The other problem, which Berg (1997) points to, is that protocols contribute to the loss of importance of information and interventions that are difficult to explicate and/or to quantify. Similar to Suchman’s (1983) view on office procedures, Berg (1997) argues that explicit statements and procedures are the end results of scientific practices, not an attribute of the process, which leads to them. By this he means that a diagnosis can be the end result of a period of work, but it doesn’t mean that the process of producing the diagnosis itself can adequately be represented as a series of explicit statements. Accordingly, these gaps in the protocols, i.e. what is not explicitly mentioned in the protocol including what stipulations are assumed, only become clear when the protocol is studied as an artefact immersed in practices (Timmermans and Berg, 1997).

The implications of these problems for the design of EMR systems is that the protocols should be used in a modest way i.e. “as means to stimulate discussion and make more complex activities possible” (Berg, 1997, pg 1087). Consequently, implementing protocols in the design of EMRs to achieve structure is discouraged as previous studies have shown negative impacts on the actual delivery of patient care caused by the disparities between the protocols encoded or inscribed in the records and the actual clinical practices (Allen, 2012; Berg, 1997; Boonstra and Broekhuis, 2010; Goorman and Berg, 2000). Therefore, Berg (1997) argues that protocols can instead be used, firstly, to enable healthcare workers to reflect on their own actions and allow insight into the rationalities of their work; and secondly, to take some coordinating tasks from the personnel thereby creating room for different, new tasks that may lead to personnel acquiring new competencies. EMR systems are therefore perceived as performing two roles of accumulating inscriptions (as in written words) and of coordinating activities of different health professionals to support patient care, which is their primary work (Berg, 1999b; Berg, 2001). Whilst benefits of EMR systems can be expected for secondary work processes such as management or administration, it is argued these should be secondary in priority when designing EMR systems (Berg, 2001; Berg et al., 1998).

2.2 Inscriptions

The concept of inscription originates from Actor Network Theory (ANT) which is grounded in a socio-technical perspective of Information Systems (IS). Basically, ANT considers IS as consisting of actors- both human and nonhumans, which are aligned to form a network. Thus, the actor network is the network of heterogeneous materials that make up the context (Monteiro, 2001). ANT provides a set of concepts to describe how, where and to what extent technology/technical artefacts such as standards influence behaviour (ibid.). The concept of inscription refers to the way technical artefacts embody patterns of use (Hanseth and Monteiro, 1997) and may be used to describe how concrete anticipations and restrictions of future patterns of use are involved in the development and use of a technology (Monteiro, 2001). The work of designers therefore involves inscribing their vision of the world in the technical content of an artefact (Akrich, 1992). In this regard, technologies have even been perceived as inscription devices (Bloomfield, 1991). In addition to the deliberate creation of inscriptions, technologies also possess inherent inscriptions that may change the work practices by introducing new work tasks (Aanestad, 2003). Mpazanje et al. (2013) further
indicate that inscriptions do not have a single format but rather come in all sorts of forms such as objectives, systems or other artefacts.

The strength of an inscription is the degree to which an inscription actually succeeds in enforcing a desired behaviour i.e. whether they must be followed or whether they can be avoided (Hanseth and Monteiro, 1997). This is based on the recognition that inscribed patterns of use may not succeed because the actual use deviates from it (ibid). This is partly due to how the inscriptions are actually translated in the use setting. In essence, technologies may inscribe weak/flexible programs of action while others inscribe strong/inflexible patterns of use (Hanseth and Monteiro, 1997).

This notion of inscription enables analysis of how various kinds of materials attempt to inscribe patterns of use, for example, Braa and Hedberg (2002) used it to explain how the District Health Information Software (DHIS) inscribed a decentralized use scenario which clashed with the existing centralized organizational structure. Therefore, the attempt to include protocols in the design of EMR systems, as is the case in this study, can be perceived as a process of inscribing protocols in the system, and the notion of the strength of the inscription is used in this paper to analyze the effect of the inscribed protocols on the antenatal care work practices, which is discussed in section 6.

3. Research Context and Approach

This study was undertaken with the aim of identifying how ICTs could be used to improve the maternal healthcare services in Malawi. The study was conducted within a broader collaborative research project on improving access and quality of maternal healthcare in Sub-Saharan Africa. The collaborating institutions were University of Oslo (Norway), University of Dar es Salaam (Tanzania) and Kamuzu College of Nursing (Malawi).

3.1 The Health System in Malawi

There are three main levels of service provision within the health system: the primary level comprises of health centres, health posts, dispensaries, and rural hospitals; the secondary level consists of district hospitals; the tertiary level includes central hospitals and one private hospital with specialist services (MoH, 2007). However, in recent years, provision of health services at community level (by Health Surveillance Assistants) has been established for some specific health services resulting in four levels of healthcare service delivery.

The majority of the population (85%) in Malawi live in rural areas (NSO, 2008). The health centres are the most easily accessible health facilities, and thus, it is where most women go to seek maternal health care. At this primary level, basic maternal and child health services are provided. These services are antenatal care, delivery (for normal cases), postnatal care, child immunization, and family planning are provided (MoH, 2007; Sharan et al., 2009). The secondary and tertiary level hospitals provide more comprehensive obstetric care, and as such, women observed with obstetric complications at health centres are referred to hospitals (ibid.). However, most women in the rural areas also use traditional medicine and have deliveries in the community using Traditional Birth Attendants (TBAs) (Kanjo, 2011).

The Ministry of Health (MoH) is (among other things) responsible for developing, reviewing and enforcing health and related policies for the health sector; for developing and reviewing standards, norms and management protocols for service delivery, and for ensuring that these are communicated to lower level institutions (MoH, 2011). The ministry is also responsible for the management of the country’s Health Information Systems and for the oversight of all monitoring and evaluation activities carried out in the health sector, which includes development of data collection tools in form of health passports (for clients), service registers and reporting forms. The health passports are used by health workers as a medical record for recording client data. These records are retained by the clients after the service.
The information recorded in the health passports is transcribed to service registers so that health facilities can have a record of the encounters. The data in these registers then form the basis for compilation of required routine reports.

Malawi is administratively divided into 28 districts. This study was conducted in three districts, focusing primarily on delivery of maternal health care services at health centre and community levels in the rural contexts.

3.2 Research Approach: The Action Research Process

In this study, a qualitative research approach was adopted with an interpretive perspective. This was done to obtain deep understanding of maternal healthcare work practices and the existing health information system. We chose the Action Research method in order to enable exploration of how ICT-based information systems can be designed and implemented to support and improve healthcare service provision at the lower levels of the healthcare system. The research was guided by the canonical action research process which has five identifiable phases of: 1) Diagnosing; 2) Action planning; 3) Action taking; 4) Evaluating and 5) Specifying learning (Baskerville, 1999).

The initial diagnosing was conducted from March to May 2010 by the first author through a situation analysis of the maternal healthcare services and the associated information system. This was done to provide understanding of work practices, information and communication needs of maternal health workers, and of strengths and gaps with the existing information system. The study was conducted in three districts in Malawi: Lilongwe, Dowa and Machinga. A total of 19 health facilities were visited, the majority being rural health centres (12). Other facilities visited were rural hospitals (3), district hospitals (2), and two obstetric care referral hospitals in Lilongwe. The essential criteria for selecting the facilities were that they had to be government-owned, had to provide maternal healthcare services, and be physically accessible by car. Different types of health facilities were visited in order to get a sense of variations in the different settings, but the primary focus was the rural health centres. During this situation analysis, data was collected through semi-structured interviews. A total of 60 health personnel were interviewed during the situation analysis on maternal health services, the majority (37) being nurse-midwives as they were the main providers of maternal health services. Other interviewees included Health Surveillance Assistant (16), Hospital Attendants (4), medical assistants (2), and a doctor (1). Programme managers at the district and national levels were also interviewed in order to understand the reporting requirements and thereby obtain a holistic view of the health information system.

In addition, data was collected through analysis of existing health data collection tools (such as registers, health passports), reports, training manuals, meeting minutes and presentations. Photographs of various documents were taken to enable detailed analysis of the content later on. In places where software was in use, such applications were analysed. Observations of health workers were undertaken during service delivery to get an understanding of their work practices and use of data collection tools. Such observations were conducted in only five health facilities, for one full day of care provision. Furthermore, in one of the districts visited, the first author attended a two-day training session on antenatal and maternity registers for health workers from several health facilities. The session had 30 participants consisting of nurse-midwives, hospital/ward attendants and Health Surveillance Assistants. It aimed at training the participants on how to fill out the registers and aggregate data for reporting.

Following the situation analysis, the first author and other researchers who were involved in the overall maternal health project (including second author and fifth author), decided to work towards implementing an EMR system to support the maternal healthcare services in two rural health centres. They decided to collaborate with by Baobab Health Trust,
a leading organization in the development and implementation of EMR systems in Malawi. Baobab had developed EMR systems to support different health services such as Antiretroviral Treatment (ART), Outpatient Department (OPD), Diabetes Management, lab specimen labelling and pharmacy but did not have any system for Maternal Health at the time. Hence, the EMR system to be developed was to be part of their suite of EMR systems.

The action taking phase involved the development of an antenatal care EMR system, as the first module of the Maternal Health EMR system. The design team consisted of two Baobab officers (a project coordinator and support/deployment officer) and the first author. The development involved discussions and demonstrations of the prototype to different stakeholders including the health service managers at national, district and facility levels and the expected end-users.

Due to a long gap between the initial situation analysis and when the system was ready for implementation, another situation analysis of the antenatal care services in the implementation sites was conducted by the first author. This analysis was conducted between December 2011 and January 2012 in order to assess the situation right before deployment and therefore to provide a baseline for evaluation. During this analysis, semi-structured interviews were used to verify previous findings and to investigate any changes that may have occurred. Observations were also undertaken during consultation sessions with clients receiving antenatal care service at the health centres. Findings from this analysis also informed the design of the software.

Once the software was ready and hardware installation completed, training of the health centre staff was conducted in March 2012 at the first implementation site. This took place over a period of four days. The training session was facilitated by the first author and Baobab staff. The session had 14 participants consisting of a medical assistant (who was also the facility in-charge), one nurse, one statistical clerk, three hospital attendants, seven health surveillance assistants and one assistant environmental health officer. The system was deployed one day after the training. Support was provided to the users by the first author and Baobab staff during the first five days of use which spanned over four weeks due to antenatal clinic schedules. After this, support visits were conducted every fortnight. During the support visits, the first author conducted observations of the health workers using the system thereby providing data that informs our analysis of the strengths of the inscriptions. The system was implemented in one health centre only although initially we had planned to implement in two health centres. This was due to time limitations for the research project.

In summary, the first author’s role in the action research project can be perceived as an insider-researcher, according to the classification of Sykes and Treleaven (2009) because she was highly involved in the intervention activities. Table 1 below summarises the data collection methods used during the action research process.

<table>
<thead>
<tr>
<th>Data Collection Method</th>
<th>Action Research Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviews (No.)</td>
<td>Diagnosing</td>
</tr>
<tr>
<td></td>
<td>Action Planning</td>
</tr>
<tr>
<td></td>
<td>Re-diagnosing</td>
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<tr>
<td></td>
<td>Action Taking</td>
</tr>
<tr>
<td></td>
<td>Preliminary Evaluation</td>
</tr>
<tr>
<td>Interviews (No.)</td>
<td>60 health workers</td>
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<tr>
<td></td>
<td>3 health workers</td>
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<tr>
<td></td>
<td>7 health workers</td>
</tr>
<tr>
<td></td>
<td>11 health workers</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Observations</td>
<td>5 facilities, 1 day per facility</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2 health centres, first site approx. 11 hours in total, second site, 15 hrs in total</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1 facility, 9 support visits</td>
</tr>
</tbody>
</table>
3.3 Data Analysis
Qualitative data analysis techniques have been used in analysing the data collected during the action research process. The primary data from the situation analysis was transcribed and organised based on themes outlined in preparations for the research. These themes included work processes, data collection tools, data requirements, challenges in care work and challenges in using the data tools. This analysis informed the design process. For this paper, the data analysis has been guided by the themes identified from related work. In particular, our data is presented around the themes of protocols and work practices and discrepancies between these two. This has further guided our presentation of the design decisions by focusing on design cases related to the discrepancies. Our analysis of these design decisions has also been guided by the concept of inscription which helps us to analyse the extent to which the decisions were inline with the protocols or the work practices.

4. CASE BACKGROUND: ANTENATAL CARE SERVICE PROVISION IN MALAWI
In this section, we present the case of Antenatal Care services in Malawi with a focus on the care protocols, the work practices, and the paper-based HIS. We highlight the challenges faced in antenatal care service provision leading to different discrepancies between the protocols and the work practices.

4.1 Antenatal Care Protocols
The delivery of Antenatal Care services is guided by protocols provided by the Ministry of Health (MoH). The Focused Antenatal Care (FANC) approach is the operational protocol for antenatal care, which is described as “an approach whereby a woman is encouraged to have a minimum of four targeted visits” (MoH, 2009). The visits are targeted in that they are supposed to take place during specific periods within the pregnancy. Specifically, the first visit is targeted during the first trimester, at 16 weeks or less, the second visit is to occur between 20-24 weeks, the third visit should occur between 28-32 weeks, and the last visit should be at 36 weeks. The care protocol is represented in a matrix format which specifies activities that should be conducted at each of the visits. Figure 1 below shows an extract of the first page of the matrix.
The Focused ANC approach emphasizes that each visit should be conducted by a skilled health care provider i.e. midwife, doctor or other qualified health care workers who has knowledge, skills and attitudes to work effectively toward accomplishing the goals of FANC (MoH, 2009). The approach is also focused on goal-directed interventions that are appropriate for the gestational age of the pregnancy. These interventions are basically aimed at early detection and treatment of problems and complications such as Malaria, Severe Anaemia, Pre-eclampsia, HIV/AIDS, and Sexually Transmitted Infections. In addition, it is aimed at providing preventive treatment. Furthermore, it aims at promoting birth preparedness and complication readiness of clients and their families through the development of a birth plan.

4.2 Antenatal Care Work Practice

During interviews, nurse-midwives said that they followed the FANC which recommends four visits for each client. The activities conducted during each visit depended on the type of visit. For new antenatal clients, i.e. the first visit, a new health passport to record antenatal care information throughout the pregnancy was issued. The clients were then weighed. Sometimes, their heights and Blood Pressure (BP) were measured as well, depending on the workload. The weighing was either done by a nurse-midwife, a hospital attendant or a Health Surveillance Assistant (HSA). The HSAs also checked the immunization history of each client to identify the clients due for immunization and they provided the immunization if necessary. Following this, the clients went for HIV testing, which was also conducted by an HSA or trained counsellor. In some facilities, syphilis testing was also done if test kits were available. Some health facilities with laboratories also conducted Haemoglobin (HB) testing. After getting (or while waiting for) the results from the lab tests, the clients went for a ‘history-taking’ session. This was normally done by the nurse-midwife but in other cases, female hospital attendants did the history taking. This session included obtaining the obstetric and medical history from the client, as well as details of the current pregnancy, such as the Last Menstrual Period date (LMP), Expected Delivery Date (EDD), gestation, planned delivery place and plan for transport. Following this, the clients were physically examined by the nurse to establish the fundal height, the foetal heart, position and presentation of the baby (among other things). Whilst examining the fundal height, the nurse would normally ask the client again about the gestation to see if it matched the nurse’s findings. After the physical
examination, the nurse scheduled the next visit and prescribed the required drugs. After receiving the drugs, the client was registered in the Antenatal Care (ANC) register for the facility and this was done either by the nurse, an HSA or a hospital attendant. The hospital attendants also dispensed drugs like Iron tablets that had been prescribed earlier. All of these actions marked the activities conducted on the first antenatal visit. However, in cases where the client had problems or complaints needing clinical attention, e.g. malaria symptoms, she was referred to the Outpatient Department (OPD) for blood testing and/or consultation with a clinical officer or medical assistant.

For the subsequent visits, fewer tasks were performed. These tasks included taking the vitals (weight & BP), providing immunization (if required), HIV testing (if required), conducting the physical examination, scheduling the next visit, prescribing and administering drugs, and registering the visit in the ANC register. Thus, even though the protocol only recognised ANC as given by a midwife or doctor, the provision of ANC in practice was a collaborative process involving different tasks performed by different types of healthcare workers.

4.3 The Paper-based Health Information System

The protocols of antenatal care were inscribed in various artefacts used during service delivery. One of the artefacts was a gestation calculator provided by the Ministry, which is shown in Figures 2a and 2b below.

![Figure 2a: Gestational Calculator (front-view)](image)

![Figure 2b: Gestational Calculator (back-view)](image)

The gestational calculator is meant to coordinate the work of calculating the gestation on the current date and calculating the Expected Date of Delivery (EDD). By placing the arrow on the calendar for the 1st day of last period against the specific date determined by the client to be her Last Menstrual Period (LMP), healthcare workers are able to check the corresponding date for the arrow labelled probable date of birth. Similarly, the gestation corresponding to the current date can be read from this calculator. Furthermore, the calculator also shows the period (in red colour) when a woman is supposed to be given SP drugs for Malaria prevention (see figure 2a). The back of the calculator (figure 2b) also contains instructions on other matters that have to be done during antenatal care. Such matters include drugs to be given to the client (and when) as well as topics to be discussed with the client. The calculator was usually placed on desks or walls in the antenatal rooms; however, it was hardly used by the health workers to calculate the gestation and EDD. Such non-use were
explained to be related to lack of accurate information in that most women did not know their LMP dates, which was necessary information for doing the calculations.

The antenatal care protocols were inscribed in the design of the health passports and ANC registers, which were meant to be used by health workers in ANC care service provision. In particular, the health passports consisted of specific pages for recording ANC care data for the client as shown in the Figures 3 and 4 below. The content and layout of these pages guided the health workers on what activities they were supposed to do for each visit and throughout the pregnancy. For instance, the nurses were required to collect a ‘summary’ obstetric history of the client recorded on the main ANC page (Figure 3), as well as a detailed obstetric history that inquired about each previous pregnancy in more detail (Figure 4). The main ANC page also included inscriptions of conditions considered to be high risk factors for obstetric complications. These high risk factors were represented using the colour red. If a woman had any of the conditions in red she was supposed to be advised (and plan) to deliver at a secondary health facility (i.e. hospital). Instructions were also included on the ANC page about other related services (i.e. TTV and HIV testing), which the nurse had to pay attention to. Thus, the inscriptions on the ANC pages coordinated healthcare work by creating awareness of what activities were expected, what had already been done, what was outstanding and the recommended courses of action that had to be taken for women with high risk factors.

Figure 3: Antenatal Care page of Woman’s Health Passport
The information from the health passports was then recorded in the antenatal care registers at the end of the visits. The clients were given a sequential registration number from the register on the first visit, which was copied to their health passport. This number was used to retrieve their record in the register during subsequent visits. In this way, all visits for a particular woman during a given pregnancy were recorded on the same page and section in the register, with each visit recorded as a row in the register. The last row of the section for each client (in the register) provided a summary of the outcomes of the antenatal care services for that woman. This was then used for compilation of a cohort report. The report was compiled on a monthly basis and sent to the district level. The aim of the report was to assess the total services given to the client throughout her pregnancy. For example, the report wanted to know the total number of visits the clients had throughout the pregnancy. For the monthly report, the clients were grouped together according to the month they started attending ANC services, thereby forming a cohort.

4.4 Discrepancies between Protocols and Work Practices

The protocols were not followed strictly in the work practice to determine the course of care given to the antenatal client due to various factors. For starters, the work of providing antenatal care was expected to be conducted by a nurse-midwife, which included activities of weighing, history taking, physical examination and recording in the registers. However, due to the high workload and limited availability of nurse-midwives in the health centres, other health providers, such as hospital attendants, and Health Surveillance Assistants, assisted the nurse in some of the activities to reduce his/her workload. Thus, they did not follow the protocol by sharing the responsibility of providing ANC. Furthermore, the lack of human resources coupled with high attendance resulted in some of the nurse/midwives opting for skipping some of the activities such as taking the BP, checking the height, or taking a detailed obstetric history. Such activities were considered to be time consuming. For the height, some of the nurse-midwives devised alternative ways such as asking the client for her shoe-size or just using their own judgment to estimate if the client was above or below 150 cms.

Another factor that affected the provision of care was lack of basic medical equipment and supplies, such as functioning weighing scales, BP machines, testing kits (for HIV, Syphilis, HB, Urine Protein) or drugs. The lack of these tools made it impossible for health workers to take the associated measurements which led them to skip these activities.
The nurse-midwives at the health centres did not follow the protocol strictly in terms of how they chose clients to be referred for delivery at a hospital. In particular, due to consideration of high congestion rates at the referral hospitals, the nurse/midwives somehow prioritized the risk cases, leaving some of the identified cases to be handled at the health centre. For example, during observation of a client consultation, the nurse identified that the client was pregnant with twins. According to the protocol, she should deliver at a secondary health facility. However the client was not ‘referred’ because of high congestion at the referral facility and the fact that she (the nurse) had previously been able to deliver twins. Thus prioritisation of referral cases was done with consideration to resources in the referral hospitals, as well as to the level of expertise of the nurse-midwife herself.

At the same time, some of the discrepancies were not intentional but as a result of misunderstanding of the protocol. In particular, during the design process, it was discovered that the nurse-midwives had misunderstood the protocol in relation to the scheduling of the ANC visits. The nurses’ practice of scheduling four visits (even if the woman started late) was incorrect in that visits were supposed to be at specific gestation periods. Thus, according to the protocol, if a woman started late it meant that she would have less than four visits. The protocol, however, accommodated deviation in scheduling if the woman’s health condition was considered to require more visits.

Some of the discrepancies between the protocol and work practice were also caused by the fact that the clients did not know their LMP date, and hence, were not able to provide this information, which was crucial for calculating the gestation (in weeks) and EDD. The nurse-midwives devised an alternative approach by obtaining the gestation (in months) from the women. They could then use this to get an indication of the month of the LMP and month of the EDD. However, sometimes the woman could not even provide the gestation and the nurse did not have any alternative basis for obtaining this information due to lack of scanning equipment. In such cases, the values for LMP, gestation, and EDD were left blank.

The challenge in obtaining reliable information from the clients on the LMP date also resulted in discrepancies on how the data from the health passports was transcribed and recorded into the antenatal care registers. In particular, when recording the value for gestation in the register, they did not record the gestation that was provided by the woman, instead, they recorded the fundal height as the gestation. Thus, the week of first visit in the register was essentially based on the fundal height examination.

Another source of discrepancy, particularly with regards to registration of clients in the ANC register, was the clients’ care-seeking practice. Clients obtained ANC services from different health facilities and in such cases, healthcare workers had to decide whether or not to record the client in the ANC register. This problem was extensively discussed during the registers training session where it was indicated that the view of the Ministry was that there were few clients moving and therefore had minimal effect on the accuracy of the health data. However, it was indicated that the movement of the clients varied among the facilities depending on e.g. ease of accessibility of the facility. As a result, this resulted in one of the following scenarios:

1. A woman who started her visits somewhere else would not be recorded in the register, especially if she was close to delivery.
2. Visits taking place elsewhere were not recorded in the register for returning clients. Hence, even though a woman actually had, for example, four visits in her health passport, the register would only have 3 visits thereby affecting the accuracy of the report.
3. Women who were transfer-ins were registered in the book as new clients. Such registration would lead to double reporting of the same woman by the different health facilities.

5. **THE EMR SYSTEM DESIGN**

The overall aim of the research project was to develop an EMR system that would support health workers in the provision of antenatal care services. In this process, the first author developed system requirements for the health centres based on the findings from the situation analysis and discussions with Baobab staff. The functional requirements for the proposed ANC system were specified as: registering ANC clients; capturing and validating client’s antenatal care data; providing alerts and reminders for patient care based on the patient data entered; reviewing client’s ANC data captured; scheduling ANC appointments; ending ANC service for the pregnancy; producing statistical reports; and reviewing a client’s ANC history for previous pregnancies (i.e. if the previous pregnancy was captured in the system). Since the ANC system was part of the suite of Baobab EMR systems, the technology and fundamental design principles of the system had to be aligned with the other existing systems. We briefly present the design principles that were applied in the design of the other existing Baobab systems (which were inherited in the design of the ANC EMR system) in the following section.

5.1 **Design Principles of Baobab EMR Systems**

Baobab adopts a Point of Care (POC) approach for operationalising EMR systems whereby health workers use computers to enter information during clinical encounters at point of care. This approach is based on the recognition that monitoring and evaluation data and patient care data are essentially one and therefore they advocate for recording data once at the point-of-care (Douglas et al., 2010). In this regard, during the design process, the aim is that the systems should “mimic existing processes and workflow in order to be as minimally invasive as possible” (Douglas, 2009, pg 21). Therefore, in designing the ANC EMR system, designers focused on understanding the antenatal care workflow and work practices in an effort to have the interface design ‘mimic’ the workflow.

The Point of Care approach implies use of the EMR systems in real-time, i.e. as healthcare services are being provided, and therefore requires the system to be efficient in use. To achieve this, Baobab adopted a touch-screen user interface as a solution that was easy to learn and use considering low computer literacy among health workers (Douglas et al., 2010). Besides the touch screen, a printer and a barcode scanner are used to form a clinical workstation. The workstation is used for the sole purpose of running the EMR application and no alternative use of the workstation is allowed.

The interface design adopts a wizard-like approach to capturing information whereby each screen is dedicated to collecting a single data element, rather than having multiple data entry fields on a single screen (Douglas, 2009). In this regard, data elements are represented as a series of screens, which allows for incorporating branching of data elements based on the data values entered. The aim of the wizard-like approach is to increase usability for a Point of Care system.

A core module in the suite of Baobab systems is a registration module for issuing patient ID numbers to enable continuity of care. The module produces bar-coded labels to be affixed to clients’ health passports. Furthermore, recognising that a paperless system is not possible, the systems are developed such that patient visit summaries can be printed onto inexpensive adhesive labels and affixed to existing paper artefacts such as the health passports (Douglas et al., 2010).
An important objective of the EMR systems is to improve the accuracy of data. In order to achieve this, two-level data validation during data entry is incorporated in the design of the systems (Douglas, 2009). This two-level validation involves creating two ranges of validation rules, one that prevents unfeasible values to be entered, and another which traps values that are unlikely but plausible if they are valid outliers (ibid). Therefore during the design of the ANC EMR system, designers aimed to identify data elements, data values, and validation rules that could be incorporated in order to improve the accuracy of data during data capturing.

Furthermore, inscribing protocols into the EMR systems, in order to help health workers follow a standard treatment protocol, is considered one of the benefits of the Point of Care model in the context of the ART EMR system (Douglas et al., 2010). Therefore, in designing the ANC EMR system, the designers aimed to identify how the protocols could be incorporated in the system as a guide to health workers during antenatal care provision. In the section that follows, we present the specific design decisions that were made during the development process of the ANC EMR system.

### 5.2 Designing the ANC EMR System - Dealing with the Discrepancies

Bearing in mind that the aim was to develop a Point of Care EMR system, the focus was to design the system according to the work practices. Therefore our presentation of design decisions focuses on cases where discrepancies between work practices and protocols were apparent and how these were addressed. We also present other cases where decisions were made to inscribe protocols in order to guide health care workers in the antenatal care process.

#### 5.2.1 Designing According to Work Practice

There are several cases where the work practices were implemented in the design of the system. In particular, due to lack of nurses, other health providers (HSAs, hospital attendants) were not restricted from entering the patient information in the system although the care protocol only considered the nurse-midwife as the ANC care provider. Thus, the scope of system use was extended to other health workers. Furthermore, the designers wanted to include validations to ensure that a client with a risk factor had the ‘planned delivery place’ indicated as a secondary health facility. This was particularly relevant for the health centres. However, this was not implemented in the system because it required ensuring the list of facilities in the system was exhaustive with clear definition of which facilities were secondary or tertiary health facilities. It also required having a clear list of which risk factors required referral. Obtaining a comprehensive list of risk factors which required referral was challenging because the health workers seemed to have their own way of prioritising which cases they referred and which ones they could handle. Hence obtaining clear definitions of which conditions really needed referral required more work to be done in close collaboration with the responsible departments, and due to time constraints on the action-research project, this was not pursued further by the designers. As a result, the nurse could decide on the course of action as she did with the paper system.

In addition, due to lack of functioning basic equipment or medical supplies such as Blood Pressure (BP) machines, weighing scales and lab test kits, the designers included options for showing that such measurements were not taken. However, for some of these data elements, alerts and reminders were still incorporated as is described in the following subsection.

#### 5.2.2 Designing According to Protocol

Protocols were incorporated in the design of the system in different ways. Firstly, the protocols were implemented to guide the care provision through the incorporation of
alerts/reminders. These alerts were mainly proposed by service managers. One such alert was related to HIV testing. According to the protocol, women should be tested during their pregnancies. Thus, an alert was incorporated for the HIV test result. If the result was entered as ‘not done’, a pop-up message would appear recommending the client should be tested. Similarly if a client was tested previously, but the ‘test date’ was more than three months ago, a pop-up message would appear recommending a new test. Furthermore, if a client had a Diastolic BP value of 90 or above, an alert was included to indicate the client was at risk of Pre-eclampsia and the need for a Urine Protein test. However, not all facilities were able to conduct Urine Protein tests, therefore, the designers considered it inappropriate to enforce capturing of a valid Urine Protein test result.

Some other alerts were also proposed by baobab staff that had worked on the other existing systems (but were not part of the design team). For instance, in line with the goal of ANC to identify women with risk factors, one of the baobab staff proposed that the system should have alerts on the patient’s dashboard showing the risk factors that were identified (i.e. if any). This required re-designing the interface of the patient dashboard in order to be able to display such information. The designers and the developer therefore decided to use colour coding on tabs where information was displayed. This would indicate if there was a risk factor under that group of information. Red was chosen to indicate existence of a risk factor and yellow to denote the data had not been entered. An example of the patient dashboard is shown in Figure 5 below.

![Figure 5: Sample Patient Dashboard for ANC EMR system](image)

Another case where protocols were inscribed is the scheduling of the client’s ANC visits. Initially designers proposed the interface design for ANC scheduling based on the existing work practice. This was developed in such a way that it firstly provided an option for the nurse to specify the time-space between the next visit, e.g. one month, and then the system would calculate and indicate the next visit date (similar to figure 6 below). The nurse would then be able to change or confirm the calculated date. However, during a demonstration with various stakeholders it was indicated by the ministry that this way of scheduling was wrong. Instead, it was recommended that the visits should be scheduled
according to the FANC approach, which meant that to schedule the next visit, the visits should be within the gestation periods as defined in the FANC matrix. It was recommended that the system should not allow booking outside the gestation periods. Based on this input, the interface was redesigned whereby the nurse would have to select the gestation period in which she wanted to schedule the visit and then the next screen would provide a date within that period (as shown in Figures 6 and 7 below). The nurses would be able to change to another date if they wanted to. Thus, in the end, the protocols were inscribed in the system in order to ensure the nurses scheduled the visits according to the FANC approach. However, during observation of the system in use at the health centre, it became evident that no restrictions had been incorporated on the selected gestation periods. Therefore, the nurse was able to schedule visits even outside the selected range e.g. if she chose 20-24 weeks, she could still schedule a date where the gestation would be at 25 weeks.

![Figure 6: ANC Visit scheduling screen 1](image1)

![Figure 7: ANC Visit scheduling screen 2](image2)

Protocols were also inscribed in relation to obtaining the obstetric history. The designers decided to link the collection of the detailed obstetric history and the summary obstetric history in the system although in practice some health workers did not always collect details of each pregnancy due to high workload. This was done in such a way that once the number of deliveries and abortions were entered, the system would request for details about each delivery and each abortion. Thus some of the details of the summary obstetric history were drawn from the details of each pregnancy. For instance, instead of asking a client if they ever had a still birth, it was determined by checking if any of the deliveries had ‘condition at birth’ captured as a ‘still birth’. As a result, the collection of details for each previous pregnancy was compulsory. However, one of the important factors in defining these data elements and their associated data values was the ability of the clients to provide the precise information as it was historical information. During the demonstration sessions, it was indicated that most women often could not remember/know the precise details (e.g. the birth weight, labour duration, gestation weeks) especially if they had many children, or if they had delivered at a Traditional Birth Attendant. Therefore, instead of having a precise figure e.g. for birth weight, it was suggested to be shown as the ‘estimated birth weight’ and three possible data values were defined: small baby (less than 2.5kg), average and big baby (above 4kg).

A significant functionality of the EMR system was the production of a monthly report. For the paper-based system, the identification of the visits was not a problem as the registers only held information for one pregnancy. However, with the EMR system, it was necessary to be able to uniquely identify each pregnancy with its associated visits over the years, for both presenting their care history as well as generating monthly reports. In particular,
ensuring that the EMR was able to generate the required monthly report was of crucial importance for both the Ministry of Health and for the health workers because the manual report compilation was a cumbersome task for them. Due to the fact that not all women came for delivery at the same clinic (and without a maternity module for deliveries) it was not practical to rely on the nurse updating the client’s record to update her status to e.g. ‘delivered’. Therefore, it was decided that this had to be automatically determined by the system. The Last Menstrual Period Date (LMP) was identified as the basis for estimating the ‘validity period’ of a pregnancy and thus the visits within that period. It was indicated that a pregnancy would not last more than 42 weeks and designers decided that it should be indicated as 45 weeks in the system. The designers were aware of cases whereby some women did not know their LMP and they suggested that the nurses should enter the data based on examination of the fundal height. Hence, even though in the work practice it was acceptable to have no indication of the LMP, it was crucial to have an estimate on the LMP date in the EMR system. More specifically, the designers proposed that the nurse should estimate the date by choosing one whereby the calculation of the gestation would equal her finding on the fundal height. This was technically possible since the interface was designed to display the calculated gestation and EDD on the same screen when specifying the LMP (similar to figure 8 below). This was discussed with future users of the system and other stakeholders during the various demonstration sessions, through which it was considered acceptable. In this way, the EMR system enforced the collection of the LMP by the care providers. However, during the last demonstration of the system to stakeholders, one of the changes proposed was that if a woman did not know her LMP, it should be recorded as unknown in the system, rather than estimated as suggested by the designers. This was recommended as the principle that health providers were supposed to follow in such a scenario. Upon presenting these changes to the software developer, we realised that having an unknown LMP value in the system would be problematic, since it was used for identifying the pregnancy. Thus, having an unknown value disrupted the operation of the system, for example, the visit summaries could not be displayed or printed without the identification of a pregnancy. It was therefore necessary for the LMP to be estimated in some way. After consulting a maternal health expert and discussing the implications of having an unknown value on the system functions, she advised that if the LMP was ‘unknown’, the system should provide an option for entering the gestation (in months) according to the woman’s estimation. This could then be used to calculate the LMP date. Thus the resulting interface for the LMP included an “unknown” button as shown in Figure 8 below.
In addition, in line with the ministry reporting requirements, it was important that the system could identify the visits associated with a particular pregnancy in order to assess the overall care given to a woman throughout her pregnancy. The aim of the report was to assess the quality of care given to the client throughout her pregnancy rather than mere ANC attendance at the facility. An important assumption of the ministry’s report was that women would go to the same health facility throughout their pregnancy. However, as presented in section 4, the care-seeking practice was that women went to different health facilities for ANC during the same pregnancy and health workers therefore had to decide whether to register the client or not in the ANC register. In the initial system design, the client’s visit numbers were automatically incremented by the system; however, considering the client’s practice, designers decided that the visit number had to be explicitly indicated by the health worker in the system, which was to include the visits done in other facilities. In this regard, the designers had to change the design of the system to incorporate the Ministry’s reporting requirements and the care-seeking practices of the clients. However, the ministry’s requirements were not fully addressed because it wasn’t all data from visits in other facilities that were recorded. In this way, the report would still have missing data in relation to the care provided by other facilities. Furthermore, considering the clients movement between facilities, instead of having the system determine the week of first visit from the gestation (or the fundal height), it was left to the nurse to specifically indicate the week of first visit. Therefore, in order to address the reporting needs, the system had to incorporate additional data elements within the EMR system instead of deducing them from the care data.

Table 2 below summarizes the discrepancies between the protocol and work practices and underlying reasons for these differences.

<table>
<thead>
<tr>
<th>Antenatal Care Protocol</th>
<th>Work Practices</th>
<th>Reason for discrepancy</th>
<th>EMR design</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANC provided by nurse-midwives, doctors or other qualified personnel</td>
<td>ANC service activities conducted by nurse-midwives, hospital attendants and HSAs</td>
<td>Shortage of nursing staff; High workload</td>
<td>Hospital attendants and HSAs included as system users</td>
</tr>
<tr>
<td>Collect full obstetric history including details for each pregnancy.</td>
<td>Collection of details for each pregnancy was sometimes skipped</td>
<td>High workload; Missing pages in health passports</td>
<td>Mandatory entry of obstetric history for each pregnancy</td>
</tr>
<tr>
<td>Measure height, weight and BP of client.</td>
<td>Height not always checked. Shoe size or visual estimation done instead. Weight and BP were not collected at some facilities.</td>
<td>High workload; Lack of functioning equipment</td>
<td>Provide for unknown option. Reminder for required tests.</td>
</tr>
<tr>
<td>Conduct Lab tests</td>
<td>Lab tests not conducted at times</td>
<td>Lack of testing kits</td>
<td>Provide for unknown option. Reminder for required tests.</td>
</tr>
<tr>
<td>Clients with a danger sign should be referred for delivery at a</td>
<td>Not all clients with a danger sign were referred for delivery at a secondary</td>
<td>High congestion at referral facility leading to prioritisation of</td>
<td>System highlights high risk factors identified for a client. No validations included</td>
</tr>
</tbody>
</table>

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secondary health facility

facility. cases. to check if clients with high risks have been referred.

Normal Clients should have 4 visits scheduled at specific gestations

Nurses scheduled the client’s visit to ensure the client had 4 visits even if she started late

Misunderstanding of protocol

Scheduling based on the FANC protocol

Determine LMP, gestation and EDD (using gestation calculator).

The LMP and EDD were not recorded as a date. Instead months were recorded or left blank.

Clients did not remember the LMP date. Lack of scanning equipment

Provide for unknown option. System estimates LMP based on gestation.

Client visits should be recorded in the ANC register

Some visits of clients not recorded

Clients attending some visits in other health facilities

Entry of the visit number by health worker instead of automatic incrementing of the visit numbers

Table 2: Discrepancies and their Associated EMR Design Solutions

6. Analysis and Discussion

In the previous sections, we showed existence of several discrepancies in the performance of antenatal care work and the underlying aspects causing them. These discrepancies were caused by staff shortages, high workload, lack of resources (functioning equipment, test kits, drug), misunderstanding of the protocol, and client-related aspects. All these aspects are similar to that which Berg (1997) calls practical contingencies that affect healthcare work. Some of these contingencies, such as lack of human and medical resources, were organisational in origin and thus, outside the scope of control of the health care workers. Similarly, aspects related to clients (such as ability to provide the LMP or their practices of seeking care in other facilities) were also outside the control of the health workers. However, some of the aspects were personal in nature in that they were related to the personal choice of the health workers in dealing with their circumstances. For instance, due to the high workload, some health workers opted to skip taking a detailed obstetric history, height and BP. Yet others tried to get an estimation of the height using alternatives like the shoe-size. Thus, such deviations were within the control of the health workers and may be seen to be closely related to the value they ascribe to such activities. Consideration of the source and nature of these discrepancies were important in deciding how to deal with them in designing the EMR system.

The adopted guiding design principles of a Point of Care, a touch screen and wizard-like interface design implied specific grouping/categorisation and sequencing of data elements and data values in the EMR system design. Thus, the system imposed a specific order and structure of antenatal care work. The designers focused on defining such structure according to the existing work practices. This can be viewed in line with Berg (2001) who argues that structure should be based on an understanding of the local work practices. At the same time, the designers aimed at inscribing protocols as a way of improving both, the data accuracy and the quality of care. These protocols were implemented for instance, in form of validation rules on data elements that were able to trigger different types of alerts. Therefore, in cases where discrepancies were apparent, the issue was whether to design according to the work practices or to the protocol. Some of the design decisions aimed at accommodating the...
discrepancies by allowing for such situations in the EMR system. On the other hand, some of the decisions were aimed at constraining or restricting the occurrence of deviations through enforcement of the protocol.

6.1 Accommodating Discrepancies: Weak Inscriptions
The discrepancies caused by lack of resources such as basic medical equipment and supplies (i.e. weighing scales, BP machines, testing kits, etc.) were accommodated by providing an option to specify the particular data value as ‘unknown’ for each of those data elements. The system, therefore, was designed to afford the collection of a specific value or an unknown value. Nevertheless, the designers still incorporated inscriptions of the protocols in form of alerts and reminders. For instance, when the HIV test was indicated ‘not done’, it provided a pop-up reminder that the client needs to be tested. Similarly when the BP was recorded to be high, a pop-up alert was provided recommending that the client needs a Urine Protein test. These inscriptions aimed at simply creating awareness of the recommended course of actions without enforcing it. These can be perceived as weak inscriptions of the protocol as they did not enforce adherence to any particular activity.

The challenge of obtaining LMP from women led to the deviation on how the ‘week of first visit’ was determined in the ANC register. As a result, the designers chose to include a specific data element for ‘week of first visit’ thereby leaving it up to the nurse-midwife to decide what to base it on. In this way, the deviation was accommodated by introducing a new data element. Thus, instead of defining the dependency in the system, the responsibility was left to the nurse-midwife. In this way, a weak inscription of the protocol was implemented.

Another discrepancy concerned how the nurse-midwives prioritised the cases to be referred to a secondary health facility. Although the health passport had indications of high risk factors, the actual prioritisation seemed partly subject to the skills of the nurse-midwife herself i.e. how comfortable she was with dealing with such cases, and what kind of risks she associated with the different conditions. Therefore the designers decided to accommodate this by not incorporating validations on such cases. Instead designers only incorporated the protocol defining conditions of high risk factors and provided a passive form of alert using colour coding. Thus, this was a weak inscription of the protocol as it did not restrict the course of action.

The designers also tried to accommodate the movement of clients among various facilities which affected the reporting requirements. This was partially accommodated through the inclusion of an additional data element for explicitly specifying the visit number. In this light, a weak inscription of the protocol was incorporated. However, other associated data elements for such visits could not be collected in the system.

By accommodating these discrepancies, the system embodied multiple rationalities and thus achieved some form of flexibility. This was achieved by implementing weak inscriptions of the protocols. Most of these discrepancies which were accommodated are those that were caused by factors outside the control of the healthcare workers. However, the discrepancy on prioritisation of high risk cases was related to personal attributes of the health worker but was accommodated with the implementation of weak inscriptions due to the additional work that was required to clearly define which conditions had high priority. This work could not be done due to time limitations of the action-research project.

6.2 Enforcing Protocol: Strong Inscriptions
In dealing with some of the discrepancies, inscribing the protocols was opted with the goal of enforcing adherence to the protocol. This was the case in dealing with the collection of the detailed obstetric history. The designers decided to link the collection of the detailed obstetric history and the summary history by incorporating dependencies between the data values. In
this way, all data on obstetric history was compulsory and collected at the same time. Thus, the designers chose to enforce the protocol in order to facilitate collection of complete obstetric history of the client. This was therefore an implementation of a strong inscription of the protocol.

Similarly, the discrepancy on how ANC visits were scheduled was addressed by enforcing the protocol in the EMR system. This deviation differed from the others in that it was caused by a misunderstanding/misinterpretation of the protocol. Accordingly, the recommendation provided by the ministry (to schedule the visits in line with the FANC gestation weeks and restrict scheduling outside the selected period) was aimed at changing the incorrect existing work practice. Thus, the system was designed to afford specific options for scheduling whilst constraining others thereby serving as a strong inscription of the protocol. However, since the restrictions were not implemented in the system, the intended strength of the protocol was not achieved as the nurse-midwife was able to schedule visits outside the selected gestation weeks. Hence, ultimately it was a weak inscription of the protocol without the implementation of the restrictions.

The lack of a precise date on LMP from the clients led to deviations on how the nurse-midwives estimated the gestation. This was accommodated in the EMR design by enabling estimation of the LMP based on the gestation (in months) provided by the client. However, due to the dependencies that had been created on the LMP value in the system, it was not possible to allow that the LMP should be completely unknown even though in practice (i.e. with the paper-based system) this was left blank. Thus, instead collection of the LMP was enforced despite the challenges in obtaining this value. The enforcement was done due to the important role, which the LMP had, in fulfilling other functional requirements for the system, such as reporting. In particular, the flexibility of a paper system supported the health providers in proceeding with their work without filling in the LMP details and this did not have any effect on the reporting requirements. However, for the EMR to be beneficial, it required enforcing the collection/estimation of the LMP. Thus, even though the report was secondary work and should be of secondary importance to care work (Berg, 2001), a crucial benefit of the system was in achieving this goal. In particular, generating the report from the system would reduce the time for compiling reports for the health workers and potentially improve the accuracy of the data reported. Hence, the EMR system design enforced estimation of an LMP value and can therefore be viewed as an implementation of a strong inscription of the protocol.

Most of these cases whereby enforcing the protocol was opted for (with the exception of the LMP) are for discrepancies caused by factors that can be seen to be within the control of the health worker. The lack of the LMP, however, was caused by client-related factors which we discuss in more detail below.

6.3 The Role of the Client as a Cooperative Actor in Health Care

Our process of designing the EMR system can be perceived as that of mapping dependencies for different antenatal care tasks. The focus is normally on defining dependencies among tasks performed by different cooperative actors. Fitzpatrick and Ellingsen (2012) state that most studies in the healthcare settings have focused on different health professionals as cooperative actors in the care process. However, our case highlights the important role that clients have in influencing whether healthcare workers are able to provide care according to the defined protocols. As Berg (1997) states, the gaps and stipulations assumed in a protocol only become clear when the protocol is studied as an artefact immersed in practice. In our case, such stipulations included the informative role of the client in the care process. For instance, since women did not remember or know their LMP dates, the health workers could not use the gestation calculator which was provided by the Ministry. The lack of diagnostic
equipment, in our case, heightened the client’s role as actors who became a source of crucial information for provision of antenatal care. Thus, there is a dependency on the information that clients provide. Our case particularly highlights their role as a primary source of information that is based on their own awareness and observations; and the consequences when the clients are unable to provide reliable information. Thus, their inability to provide the required information affected whether the health workers were able to fulﬁl their tasks. This, consequently, led to discrepancies in the care process.

The role of clients was also visible during the design process in the present study as it inﬂuenced the design of the EMR system. For instance, in deﬁning the data elements for the obstetric history and their associated data values, consideration of the clients’ ability to provide information about births that happened at a Traditional Birth Attendant inﬂuenced the deﬁnition of the data elements as well as the associated data values. In addition, taking into account that clients attended visits in other facilities led to addition of a new data element, which inﬂuenced the kind of data that was collected in the system. Thus, the clients’ practices of seeking care also played a role in inﬂuencing the EMR design. Therefore, when analysing healthcare work to inform design of EMR systems, it is important to consider clients as important actors who directly affect how the care process unfolds, and consequently, affect the emerging EMR system design.

7. Conclusion
The aim of this paper has been to contribute to the understanding of how work practices and protocols inﬂuence the design of EMR systems in developing country contexts by looking at three speciﬁc areas from our case: what discrepancies existed between protocols and work practices; how these discrepancies were addressed in the development of the EMR system; the resulting effect on the EMR system design.

Several discrepancies were observed between work practices and protocols in the provision of antenatal care. These discrepancies were caused by various contextual factors such as limited availability of human resources, high workloads, lack of medical equipment, and misunderstanding of the protocols. Therefore in developing the EMR system for antenatal care, the design process involved making decisions on how to address these situations. Some of the design decisions made were aimed at accommodating the discrepancies, and, thereby inclining the design more towards the existing work practices. At the same time, some of the design decisions were more inclined towards the protocol aiming at ensuring adherence to the deﬁned protocol. Nonetheless, in balancing the work practices and protocols, it is not entirely an issue of choosing whether to go with the work practices or the protocols, rather it is about the varying degrees in which the protocols can be inscribed in the system. In some of these cases, even though the work practice took precedence, the protocols were still inscribed but in form of weak inscriptions, only serving a purpose of promoting awareness of the recommended course of action. Whilst in other cases the decisions aimed at implementing strong inscriptions of the protocol that would prevent occurrence of deviations. However, not all strong inscriptions achieved the intended adherence to protocol in the work practice. Hence balancing work practices and protocols in EMR design should be perceived as a process of deﬁning which inscriptions of the protocol to incorporate, and the desirable strength for the inscriptions.

Reflecting on our design decisions, it is challenging to generalise or claim for a speciﬁc strategy for deciding, which circumstances should resolve to weak inscriptions and which ones should aim for strong protocols. However, weak inscriptions seem to have been preferred in dealing with most discrepancies caused by factors outside the control of the healthcare providers. Simultaneously, strong inscriptions were opted for factors which were considered to be within the control of the health workers. But then, we also ﬁnd exceptions to
these rules in both cases. Ultimately the decisions were influenced by various factors including who was (and how they were) involved in the design process and this is a discussion we plan to tackle in our future work. Consequently, what our case highlights are the various aspects that affect the performance of healthcare work and how they inevitably influence the design of EMR systems.

One of these important aspects is the client who plays a crucial role of providing important information that affects how the care process emerges. Thus the clients can be perceived as cooperative actors in the provision of health care. However, this role is often taken for granted in most studies conducted in developed countries but the lack of resources in developing countries heightens the client’s role in the care process. Thus, in analysing healthcare work to inform development of EMR systems, it is important to expand the scope of healthcare work to consider the roles and practices of the clients/patients in addition to those of the healthcare providers.

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Appendix 4: Paper 4

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Stakeholder Participation in the development of an Electronic Medical Record system in Malawi

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ABSTRACT
In this paper we are concerned with stakeholders’ participation in the development of an Electronic Medical Record (EMR) system for health facilities in Malawi, Africa. We draw on insights gained during the process of an Action Research project, which involved different stakeholders. We examine the different roles and forms of participation of these stakeholders. Through this, we illustrate how participation changes over time and co-evolves with the progress of the project. Our analysis also reveals that, in rural low-resource settings, expected end-users of EMR systems do not always have the health domain knowledge or expertise to effectively participate in such design projects. Therefore, participation of managers and other health domain experts is essential in order to supplement users’ limited specialized knowledge of the domain.

Author Keywords
Stakeholder participation, EMR system development, Malawi.

ACM Classification Keywords
D.2.10: Design, methodologies, human factors, H.5.m: Participatory design.

INTRODUCTION
The central focus of Participatory Design (PD) has been restricted to the involvement of future end-users in the development of Information Systems (IS) and to relationships between end-users and designers (Simonsen & Hertzum, 2012). The ultimate goal of PD is for users and designers to work as full partners in design processes whereby users take part in all types of decisions (Bratteteig & Wagner, 2012; Robertson & Simonsen, 2012). In early PD research projects, stakeholders, such as managers, were deliberately left out from design processes due to fear that they would silence the voices of workers (Kensing & Blomberg, 1998). Managers were considered a privileged group (compared to workers) that expressed how they thought work should be performed under ideal conditions, but, at the same time, they lacked important insights of the day-to-day work being conducted (Bødker et al., 2004).

However, other studies highlight the important roles different types of stakeholders play in the design process, particularly in the context of large-scale IS projects dominating the developed world (Dalsgaard, 2012; Johannessen & Ellingsen, 2012; Oostveen & Van den Besselaar, 2004; Simonsen & Hertzum, 2012). In the context of developing countries, several studies have similarly argued that participation needs to be extended to other types of stakeholders for the successful implementation of IS, especially within the public health sector (Braa, 1996; Byrne & Sahay, 2007; Korpela et al., 1998; Puri et al., 2009). A challenge for PD, therefore, is how to manage and align the different stakeholders’ interests. In answering this, scholars increasingly seek to develop processes that enable active stakeholder participation (Robertson & Simonsen, 2012).

In recognizing that participation is not a homogenous concept, but rather takes many forms in practice (Cavaye, 1995), it is important to understand the nature and forms of participation that take place among different types of stakeholders, and, herein, their resulting influence on the system design. In this paper, we analyze forms of participation of different stakeholders during the development of an Electronic Medical Record (EMR) system for Antenatal care in Malawi. Our aim is to address the question: what are the roles and forms of participation of different stakeholders in the development of EMR systems in Malawi? In addressing this question, we contribute to understandings about aspects of design in which stakeholders contribute. In so doing, we respond to a call for increased focus on outcomes of participatory processes (Balka, 2010; Puri et al., 2009).

RELATED WORK
Describing Participation: Forms of participation
Within the PD literature, (user) participation has broadly been described as involvement of future users in work activities during system development (Bjerke & Bratteteig, 1995). However, it is interpreted and applied in different ways and hence, there are many ways to define and categorize participation (Bergvall-Kåreborn & Ståhlbrost, 2008; Cavaye, 1995).

Simply put, participation is perceived as varying from direct involvement, where all parties affected by the system are involved, to indirect, where representatives serve on decision-making committees (Ives & Olson, 1984). Another way of classifying participation is provided by Mumford (1981) who identifies three forms of participation: consultative, representative, and consensus. The consultative form is the lowest level of participation, where the bulk of design decisions are left to designers, who aim at ensuring that the objectives and the system are based on the users’ needs. Representative participation has a higher level of participation, whereby...
a design group consists of user representatives and designers, and the users have an equal say in any decision. Consensus participation attempts to involve all members of user departments continuously throughout the design process.

Cavaye (1995) provides another way of describing participation. She identifies six dimensions or attributes for describing user participation: *type, degree, content, extent, formality and influence*. These are presented in Table 1 below.

<table>
<thead>
<tr>
<th>Attributes of participation</th>
<th>Possible values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>All users, representatives of users</td>
</tr>
<tr>
<td>Degree</td>
<td>Advisory capacity, sign-off responsibility, part of team, full responsibility</td>
</tr>
<tr>
<td>Content</td>
<td>Technical design, social and technical design</td>
</tr>
<tr>
<td>Extent</td>
<td>Project definitions, requirements definition, building, testing</td>
</tr>
<tr>
<td>Formality</td>
<td>Formal, informal</td>
</tr>
<tr>
<td>Influence</td>
<td>Input ignored, contribution considered, input taken seriously</td>
</tr>
</tbody>
</table>

**Table 1. Dimensions/Attributes of user participation (Cavaye 1995)**

The *type* of participation is about the proportion of users that participate (ibid.). This is also associated with the different stakeholders and their roles (Bergvall-Kåreborn & Ståhlbrost, 2008). The *degree* of participation is defined as the level of responsibility that users may have during participation (Cavaye, 1995). However, this seems closely related to the dimension of *influence* as Ives & Olson (1984) (whom Cavaye draws on) define the degree as “the amount of influence the user has over the final product” (Ives & Olson, 1984, pg.590). Influence is perceived as the effect of participation on the development (Cavaye, 1995). The *content* of participation relates to how users are involved in different aspects of the system design, i.e. either the technical or social aspects or both. *Extent* of participation looks at participation during different phases of the development process. *Formality* relates to whether the participation is formally organized or whether it takes place through informal relationships.

Cavaye’s dimensions and attributes differ from Mumford’s classification in that it looks at more specific details of participation. For instance, Mumford’s classification can be viewed as based on the dimensions of who participates (i.e. *type*) and the *degree* of participation. Cavaye’s dimensions have been considered a useful framework for analyzing research on user participation, for instance, Lynch & Gregor (2004). However, as noted by Bergvall-Kåreborn & Ståhlbrost (2008), most PD literature does not clearly describe and discuss the forms and attributes of participation that take place within projects. We adopt Cavaye’s dimensions of *type, degree, content, extent and influence* in an effort to describe and characterize the kinds of participation that came about in our study. However, we do not use the dimension of formality as we find the definitions of *formal* and *informal* somewhat unclear.

In the following, we explore how PD literature perceives the role of different stakeholders in design processes.

**Stakeholder types and roles in PD**

Stakeholders are defined as people or groups of people having a stake in an information system (Avison & Fitzgerald, 2006). In PD and IS in general, this has often meant users of various kinds (Avison & Fitzgerald, 2006; Bødker et al., 2011). However, Avison & Fitzgerald (2006) categorize stakeholders as: those on the organizational/business unit side, generically known as the users; those on the development side (e.g. programmers, designers), and those external to the boundaries of the organization (e.g. customers, shareholders, sponsors, society, etc.).

Generally, there is no clear understanding or consensus about the term ‘users’, i.e. who it encompasses, despite the extensive use of the word and numerous studies on user participation (Cavaye, 1995; Iivari et al., 2010). Robertson & Simonsen (2013) define users as those who will interact with the technology being designed. These people also go by the name ‘end-users’ (Avison & Fitzgerald, 2006; Damodaran, 1996). In some cases, users have been considered to encompass senior management who may use the system’s output, and middle management who supervise the work affected by the system (Cavaye, 1995; Mumford, 1981). Managers and operational staff are often considered to be different types of users or user groups. It is recommended that each user type is involved in decisions concerning design of the facilities they will use in the future, i.e. the ones that are relevant to them (Bodker et al., 2011; Damodaran, 1996).

Bodker et al. (2004) recommend that users considered for participation should have: knowledge of the relevant work domains; professional respect among their co-workers; and enough time to participate in the project. Furthermore, Bodker et al. (2004) advocate a ‘principle of anchoring visions’ which promotes involving other staff members so that they can keep tabs on design projects and have opportunities to provide feedback.

Managers’ main role within PD, apart from being potential (output) users of systems, has been to create an environment that fosters user participation and motivates subordinates to participate (Avison & Fitzgerald, 2006; Bodker et al., 2004; Damodaran, 1996). This includes allotting staff, time, finance, and information resources necessary for making user participation happen (ibid.).

Designers are considered responsible for design projects, which includes planning and conducting the projects (Bodker et al., 2004). It is further indicated that it is not a designer’s job to resolve political conflicts that may emerge, but rather develop different design visions and assess consequences for the parties affected (ibid.).

Apart from users, managers and designers, the involvement of other types of stakeholders has been highlighted in recent PD literature (Dalsgaard, 2012;
Johannessen & Ellingsen, 2012; Oostveen & Van den Besselaar, 2004; Simonsen & Hertzum, 2012). This is primarily due to an increased complexity in PD projects being undertaken, which are more and more large-scale. For instance, in the development of an EPR system for a Danish hospital, Simonsen & Hertzum (2012) identify a range of stakeholders, such as politicians and strategists engaged in health care at national level; the vendor; the EPR unit; unit management, physicians and nurses. The authors argue for a sustained PD approach that promotes exposing designs to use in real-situated work practices (ibid).

The multiplicity of stakeholders brings about challenges on how different interests can be aligned. Simonsen & Hertzum (2012) further state that the challenge for PD is “to argue how PD, with its direct involvement of end-users, is an effective means to manage, mesh and meet the needs of these different interests” (Simonsen & Hertzum, 2012, pg.18). They propose a strategy for identifying and relating different stakeholders’ interests, which potentially can be used to argue for a PD approach that focuses on end-users’ work practices. Conversely, Johannessen & Ellingsen (2012) argue that design should be viewed as an activity, which is collectively negotiated among many stakeholders, and in which designers or technology providers serve as mediators. They further argue that the roles between designers and users are not automatically given or fixed, but depend on the mutuality of the relationships among the stakeholders. Additionally, they state that the nature of the roles can vary, depending on the phase of the design process. However, they do not fully examine the forms of participation of the different stakeholders.

**PD in Developing Countries**

Several studies have examined participatory design within the context of developing countries in relation to Health Information Systems. These studies also advocate a need to involve multiple stakeholders at various levels, including the community to be served by health workers (Braa, 1996; Byrne & Sahay, 2007; Korpela et al., 1998). Byrne & Sahay (2007) also argue that participation may extend to stakeholders outside a particular sector. Due to the existence of multiple stakeholders, Puri et al. (2009) propose that participatory design should be conceptualized as a process of building participatory networks, which emphasizes the diversity of types of participation that need to be cultivated.

Other related studies have emphasized challenges of participation in developing country settings. Lack of basic computer skills and limited exposure to IT among users affect their ability to participate, which leads to limited contributions to the design (Kimaro & Titlestad, 2008). Another challenge identified is the busy schedule of health workers, which makes it difficult to participate in design processes (Elovaara et al., 2006).

**RESEARCH CONTEXT AND APPROACH**

The study was conducted within a collaborative research project on improving access and quality of maternal healthcare in Sub-Saharan Africa. The collaborating institutions were three universities from Norway, Tanzania and Malawi. The case reported in this paper was conducted within the Malawi public health system.

The Ministry of Health provides 60% of the health service in Malawi. For the majority of the population, basic health services are obtained mainly from rural health centers, which are characterized by low staffing levels, lack of qualified health professionals (e.g. doctors and nurses), and poor basic infrastructure (Mueller et al., 2011).

At a national level, the Ministry of Health is responsible for developing and enforcing policies and standards for service delivery. This includes managing the country’s Health Information System (HIS) and developing HIS data collection tools in form of health passports (for clients), service registers, and reporting forms used in health facilities. Below the central level, the Ministry is divided into districts. Each district is headed by a District Health Officer (DHO). The management team of the district also includes a District Nursing Officer (DNO) responsible for nursing and maternity services. The district office has specific program managers who are responsible for monitoring and coordinating specific health programs. The district health office has an assistant statistician who is responsible for the Health Management Information System (HMIS).

**Research Approach**

The data presented in this paper was collected as part of an Action Research (AR) project exploring how ICTs can be designed and implemented to support maternal health services in rural health centers in Malawi. The study adopted a qualitative research approach with an interpretive perspective. The first author was involved throughout the AR phases of diagnosing, action planning, action taking, and evaluation. Rather than presenting in detail the cycles of the AR project, we describe here how the data was collected during the diagnosing phase. The activities involved during the phases of action planning, action taking and evaluation are described in relation to the system development in the next section. We have opted for this, since our primary focus is on understanding participation within system development processes.

Diagnosing was conducted through a situation analysis of the maternal healthcare services and the associated information system. Different types of health facilities were visited to get an overall understanding of the health system but the main focus was on rural health centers. A total of nineteen facilities were visited. Data was generated through interviews with health workers involved in maternal health services delivery. A total of 60 health workers were interviewed, the majority (37) were nurse-midwives who were main providers of maternal health services. Program managers, at the district and national levels, were also interviewed. Observations of some of the health workers during service delivery were conducted in five health facilities, for one full day of care provision. Analysis of existing health data collection tools (such as registers, health passports), reports, meeting minutes and presentations was also done. In addition, in one of the districts, the first
Following the situation analysis, the AR team decided to explore implementing EMR systems for maternal health in rural health centers. The team decided to collaborate with a local Non-Governmental Organization (NGO), which, at the time, was in the process of commencing a project on EMRs for maternal health to be implemented in two urban hospitals. The first author was located at the NGO’s office during the development process and took on the role of a researcher-designer. The data, thus, is a collection of her observations, interviews, software analysis, document analysis, and participation in development activities.

Our analysis is guided by related literature on participation. In particular, we describe the stakeholders and their participation along the dimensions proposed by Cavaye (1995). In the next section, we provide an overview of the development process.

OVERVIEW OF THE EMR DEVELOPMENT PROCESS

The development process of the EMR system can be viewed as consisting of two main phases. The first phase focused on developing the system for urban tertiary-care hospital settings. The NGO was in charge of this process. The second phase focused on the rural health centers and the researcher-designer led the process.

Phase 1: EMR system for the hospitals

Requirements Analysis

The process began with a situation analysis of services at the hospitals. This situation analysis was conducted through interviewing different types of health workers at the facilities and examining documents such as client health passports and service registers. Meetings were also held with the Ministry of Health and an expected donor. Through this process, a project proposal, system requirements, and software specification documents were developed.

Coding and testing

The software specifications were used as the basis for commencing the coding of the software. Intermediate versions of the software were made available for internal testing within the NGO. Some of the intermediate versions were also demonstrated to health workers at one of the hospitals, to the Ministry and to a team of representatives from hospital/district management and other service delivery partners (i.e. research institutions and other NGOs). Several cycles of coding and testing were conducted. However, due to several circumstances within the NGO, development of software for the hospitals was given lower priority and eventually put on hold. Due to time constraints, and with an interest in making progress on the research project, the researcher identified a developer who could continue working on the software aiming at implementation at the health centers.

Phase 2: EMR system for the health centers

Requirements Analysis

System requirements for the health centers were based on findings from the situation analysis conducted during the diagnosis phase. A preliminary report was produced summarizing workflows for different maternal health services, data requirements, and challenges with the existing HIS. The content of the report was verified through discussions with health workers in two health centers. Meetings were also held with researchers in the maternal health project and the NGO’s staff. During these meetings, additional systems requirements were defined. Selected implementation sites were also visited to obtain clarifications on their specific work practices, and the planned implementations were discussed with the health center staff. A system requirements document was then produced, defining overall system designs, required hardware, and software requirements.

Coding and testing

Guided by the requirements document, the development of the software proceeded. The cycles of coding and internal testing also continued. Intermediate versions of the software were demonstrated to health workers at the health centers. Furthermore, while the software was being developed, additional interviews with and observations of the health workers were conducted. The findings were used as input for the software design. The system was also tested by way of entering previous data from the Antenatal registers.

Prior to deploying the system at the health center, a demonstration of the system was organized. Representatives from the Ministry at national level, district level, and some of the ministry’s service delivery partners (who had been involved in previous demonstrations for the hospital system), attended the demonstration. Feedback from this demonstration prompted further coding. After this, a second demonstration was organized. The same organizations were invited, in addition to one health worker from the health centers, and another researcher in the maternal health project. Additional feedback, provided during the second demonstration, was incorporated into the software prior to deployment.

System deployment and training

The deployment of the system began with the installation of hardware at the health center. This included installing a power system (solar panels, batteries and power sockets) and computer network (network switch and ports). Once the installation was done, a site visit was conducted in order to test the functionality of the power and network installations. During the visit, a meeting was held with some of the health workers to plan the training. The dates, time, location and participants of the training were identified during the meeting.

The training was conducted at the health center over a period of four days, in the afternoons to allow services to be provided in the mornings. The training consisted of ‘theoretical’ sessions covering topics on patient records more generally, and practical sessions that were focused on learning how to use the EMR system.

System in Use

The system was operational one day after the training. On-site support was provided during the first five days of use, which spanned four weeks due to the schedules of the Antenatal clinic. While using the system, several challenges were identified. These concerned navigation of
participation, development side and the external side. In (2006), we categorize the participating stakeholders as situation analysis; therefore the

Not all available staff were interviewed during this

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be the organization.

In this section, we describe the participants involved (i.e. the type of participation), when they participated (extent), what they participated in (content), the degree of participation, and the resulting influence on the system design/outcome. In following Avison & Fitzgerald (2006), we categorize the participating stakeholders as belonging to the organizational/business unit side, the development side and the external side.

Stakeholders within the organization

Considering that the implementation of the EMR system was aimed for health facilities, they can be viewed as the organizational unit in itself. However, the Ministry of Health, which operates at multiple levels, owns these facilities. Thus, in our case, we consider the Ministry to be the organization.

Users

The health workers at the facilities were the expected end-users of the system, i.e. those who would directly interact with the system. In our case, we had two groups of end-users, those at the urban hospitals and those at the rural health centers.

The expected end-users at the hospitals consisted of nurse-midwives, HMIS data clerks, and Health Surveillance Assistants (HSAs) involved in Antenatal care service delivery. Their participation began during the situation analysis where they provided information on their existing workflows and work practices, hence taking on an informative role. However, some of the end-users also provided explicit input on the proposed system. For instance, one nurse said that they would not enter data in the system if they also had to write in the client’s health passport. This had implications on the system functionality. Thus, the end-users’ degree of participation in defining the system requirements was also consultative. Not all available staff were interviewed during this situation analysis; therefore the type of participation was rather representative. The information from the end-users was used to define the software and hardware requirements thereby influencing the technical aspects of the system design.

Once an intermediate version of the software was available, the expected end-users participated in reviewing the software through a demonstration of the software, which was conducted at one of the hospitals. An open invitation was made for all the health workers in the Antenatal care unit to attend and therefore more users participated in the session. Still more, not all the unit’s staff attended, since some were off-duty and others had to attend clients. The content of their participation consisted of feedback and clarifications on the Antenatal care workflow, the activities at each point of care and the associated data requirements. Through this, the users provided input on how to group and sequence data elements, data values and required validation rules. Thus, the feedback defined the data requirements, the software logic, and the interface design thereby influencing the software design. The degree of participation was therefore decisive.

At the health centers, the nurse-midwives and hospital attendants were the expected end-users of the system. Their participation started during the situation analysis of maternal health service. The health workers played an informative role, providing information of the existing work practices, the HIS data requirements and challenges faced. Following the decision to work towards developing an EMR system, the nurses were involved in verifying the findings on the service workflow and data requirements. The planned implementations were also discussed. The health workers were consulted in determining the server and workstation installation locations, which influenced the definition of the hardware requirements.

The health workers were also consulted on the software functionality that they thought would be useful for their work. For instance, one nurse expressed the functionality she would have liked to have in the system as follows: “In the system, all the [client’s] history will be entered right? It is important because maybe she loses the [health passport] book, in the system it will be there, that means it will remind you that this person, although she lost the book, she has this particular problem.”

But since an intermediate version of the system for the hospitals was already available, the required functionality expressed by the health workers had already been incorporated in the existing design of the hospital system. Hence their suggestions did not influence the design.

The nurses and attendants at the health centers also reviewed the software during demonstration sessions at their facilities. The nurses provided feedback on the possible data values, for instance, for capturing abortions, and how the captured data could be displayed for review. Thus their participation during the testing was decisive. This influenced the data definitions and software interface design. However, in some cases, the nurses were unable to provide clarifications in some areas, for instance, whether the place of delivery should be the name of a specific health facility or whether it should just be generic (e.g. hospital, health center, home, TBA).

In one of the health centers, one of the expected end-users, a hospital attendant, also tested the registration module with previous clients’ data from the registers. However, the attendant was not a current user of the antenatal registers and therefore was not well conversant with the requirements. Furthermore, one nurse from the health center participated in reviewing the software in the final demonstration session conducted with various stakeholders.

During the training, fourteen health workers participated in the training at the health center. The group consisted of those who had been identified as the expected end-users (i.e. one nurse, two hospital attendants, two HSAs, and a
statistical clerk) as well as other facility staff (the facility in-charge, five HSAs, one environmental health officer, and one hospital attendant from the Outpatient Department). Several observations were made during the training, for instance, it was discovered that the power and network ports created challenges when connecting the cables. They were installed facing down and the participants could not see how to connect to them. The ports were re-installed; thereby the hardware design of the system was influenced.

Discussions during the training also led to changes in the software interface design. For instance, after demonstrating the software to the participants, a question concerning who would be entering the information in the system, was raised. The participants indicated that it would be too much work for the nurse. A lengthy discussion concerning the workflow emerged and it was agreed that the software should be changed to allow the client’s vitals (which were currently designed to be entered together) to be entered separately. This was so that the attendants and HSAs could enter some of the vitals and the nurse could enter the others. Consequently, the health workers also contributed in redefining the service workflow, who the end-users would be, and the scope of system use thereby influencing both the work practice and software design.

Once the health workers started using the system, several challenges were identified, for example, navigating the software, increased consultation time with the clients, and an unclear workflow. The observed challenges were discussed with the nurse and it was agreed that the task of capturing the patient history should shift to the other health workers, thereby influencing the work practice by redefining service work flow and scope of system use. Changes were also made to the software interface design.

Managers

There are three groups of managers in our case: those at the health facilities, the district level and national level.

At the health center, the facility in-charge was the overall manager and was therefore consulted in order to obtain approval to conduct the study at the health center. During the process of determining the requirements, the in-charge was involved in discussions of the planned implementation and was consulted on the physical and security installations. This in turn influenced the hardware and security infrastructural requirements. The in-charge also played a consultative role in planning the training together with the nurse i.e. determining who should be trained, where and when training should be done at the health center. He also participated in the training. Furthermore, following the training and deployment of the system at the health center, more HSAs became end-users, and the HSAs supervisor had a role in ensuring their availability to assist at the antenatal clinic in registering clients in the system. However, the supervisor was not involved in the process until the system was in use.

At the district level, the District Health Officer (DHO) was consulted in order to obtain approval for undertaking the projects. During the situation analysis for the health center project, the maternal health program coordinator and HMIS statistician were informants on the required reports and this was used later to define the system reporting requirements. For the hospital project, the DHO and the District Nursing Officer (DNO) were involved in formulating the project proposal. The district managers were also managers of the urban hospital and therefore the DNO and other hospital matrons were consulted during the development of the system requirements for the hospital. They also participated in reviewing the software during demonstrations at the hospital (together with the end-users), during which the data requirements, system logic, and interface designs were defined thereby influencing the software design. The DNO also sent representatives to demonstration sessions conducted at the NGO’s offices, for both the hospital and health center systems. Other stakeholders, including the district HMIS statistician, attended these demonstrations, during which similar feedback was provided on the software design. Furthermore, after implementing the system at the health center, observed challenges were discussed with the DNO and approval was sought to shift tasks from the nurse to other staff. The DNO also provided clarifications on some of the observed issues and advised on how to address them.

At national level, the Ministry of Health was consulted in the formulation of the project proposals and their approval was sought for both projects. The Ministry was consulted during the development of the system requirements for the hospital system. The ministry was also involved in reviewing the software through the demonstration sessions that were conducted. During these demonstrations, feedback included additional data elements, required validations on the data elements, the inclusion of care protocols, changes to the data values, changes in the terminology for some of the data elements, additional functionality that would enable editing of data entered. Some of this feedback was changes to what nurses at the health facilities had specified in previous demonstrations, for instance, how to capture abortions. In this way, they contributed to defining the data requirements, the software logic, functionality, and interface design. Furthermore, approval was sought from the Ministry to include visit summary printouts that would replace writing in the health passports.

Following deployment of the system at the health center, the Ministry was also consulted with regards to the shifting of some tasks from the nurse to hospital attendants and HSAs. The ministry was against shifting tasks to the HSAs since it could affect their primary work, which was community work. However, it approved shifting the tasks to the maternity hospital attendants and provided a facilitator to train them.

Stakeholders on the development side

The stakeholders on the development side consisted primarily of the NGO (which provided the hardware and software technology) and the researchers in the maternal health project.

The NGO was in charge of the EMR system for the hospital settings and therefore had full responsibility of
the project activities. However, for the health center project, the researcher-designer had full responsibility of the activities. Nevertheless, several aspects of the system design were predefined for both projects. This included the choice of the system hardware infrastructure, which included low-power consumption servers, touch-screen computers and the power setup. The NGO technical staff was at the core of defining the hardware and security requirements for the sites. This required clear definition of the use setting, i.e. the physical locations for server and the ‘points of care’. The staff together with the researcher, and the health workers at the sites determined this. In addition, the NGO was responsible for procuring and installing the hardware and security infrastructure at the sites.

Furthermore, several aspects of the software were predefined by the NGO. In particular, the use of a touch-screen interface was adopted and the interface design adopted a wizard-like approach to capturing information; whereby each screen was dedicated to collecting a single data element, rather than having multiple data entry fields on a single screen. In this regard, defining the workflow and data requirements was central to the software design. The project coordinator, support & deployment officer and the researcher assumed the role of designers in the projects. The designers were responsible for facilitating project activities, which included developing project proposals, conducting situation analyses, developing system requirements, software specifications, budgets, and work-plans. The designers interacted with the various stakeholders to define the system requirements, which included both technical (i.e. software and hardware) and social aspects (e.g. work flow, expected users etc.). The designers were responsible for testing the software internally and facilitated the demonstration sessions with other stakeholders. The designers, therefore, assumed the role of mediators between the different stakeholders and the software developer. This involved negotiating the requirements. For instance, during one of the demonstration sessions, it was indicated that the system should allow the possibility to have an unknown value for the Last Menstrual Period (LMP) date since most women (i.e. ANC clients) did not know this date. However, after communicating this to the software developer, it was made clear that having an unspecified value would pose challenges to the functionality of the system. That is, the value was to be used as a basis for identifying a pregnancy. After pointing out this challenge to one of the involved stakeholders, it was proposed that in cases of an unknown LMP, the software should ask for the gestation (in months) instead. The LMP should then be calculated (in the background) based on the gestation.

The researcher-designer was also responsible for organizing the deployment and training. This involved installing, configuring and testing the software on the servers and computers. Further, she was involved in testing the hardware installations at the health center and planning of the training together with a training officer and health center staff. The researcher-designer and training officer facilitated the training and provided support to the users once the system was operational. The researcher was responsible for resolving identified challenges and this included requesting software modifications to the developer, discussing with the end-users, the NGO staff, managers at district and national level, and organizing additional training for the end-users.

The software developer was responsible for software coding, thereby implementing the specified requirements. As presented above, some of the feedback from the stakeholders could not be implemented as it was in conflict with other requirements or adopted design principles. Furthermore, some of the functionalities and interface designs for the Antenatal EMR were adopted from other existing systems e.g. the registration module.

**Stakeholders external to the organization**

The external stakeholders involved in the development process were representatives from the ministry’s service delivery partners and donors.

**Health Service Delivery Partners**

The Ministry works with various partners such as NGOs and research projects that assist in delivery of health services in some health facilities. Some of these institutions were already using other EMR systems from the NGO. These partners mainly participated in the software reviews during the demonstration sessions and contributed in defining the data requirements, the interface design, and system workflow.

**Donors**

Two different donors provided funding for the implementation of the EMR systems in the two settings. The funding for the hospital implementation came from a project with an interest on Prevention of Mother to Child Transmission of HIV (PMTCT). The donors were consulted during the development of the project proposal. The PMTCT services were closely integrated within the Maternal and Child healthcare services and therefore, the NGO decided to develop a comprehensive system consisting of three modules for Antenatal care, Maternity and Child care, starting with the Antenatal care module. However, to address the PMTCT services, a central requirement for the hospital project was to integrate the Antenatal care EMR system with the Anti-Retroviral Treatment (ART) EMR system that was in use at the hospitals.

On the other hand, the funding for the health center EMR system was from a project on maternal health and therefore implementing systems for HIV/AIDS was not considered crucial. Therefore, this defined the scope of the EMR system implementation at the health center. The donors, however, were not directly involved in the development process.

**Antenatal Clients**

The clients were providers of the system input i.e. data that was to be collected with the EMR system. During the testing, with the stakeholders, considerations of the clients’ ability to provide the information influenced the definition of the data requirements and the data values. In addition, following the design decision to have visit summaries from the system stuck in their health passports, the clients became users of the system output as they were expected to be able to read details such as
their next visit date. However, the Antenatal clients did not participate in the development of the EMR system, since this had not been considered.

Table 2 below summarizes the participation of the different stakeholders along the dimensions of degree, extent, content and influence.

**DISCUSSION**

The analysis shows different stakeholders’ forms of participation. The type of participation, which is about the proportion of users who participate (Cavaye, 1995), was mostly representative, although in some situations it was intended to have all the users participate. This relates to the character of healthcare work, i.e. it is challenging to include all health workers in demonstration sessions, since some attend to patients and others are off-duty. This is echoed in other studies that have described difficulties for health workers in developing countries when participating in design processes (e.g. Elovaara et al., 2006). This further confirms Cavaye’s (1995) anticipation that it is more likely that participation will be representative. However, defining the type of participation itself is not unproblematic. This dimension assumes the possibility of being able to clearly and fully define who the users are. But, as we saw in our case, the composition of end-user groups was not consistent throughout the process; rather, it changed as the development progressed. In particular, at first, only the nurses and the maternity hospital attendants were considered end-users of the system at the health center. This consideration was based on the existing work practice. But, in planning the training, the Health Surveillance Assistants and statistical clerk were included as end-users. Similarly, introducing the printouts for the health passports changed the clients from having a status as users of the service, to being direct users of the system output. Thus, the roles of the stakeholders changed during the design process, which was influenced by changes in the system design itself. Furthermore, whilst Cavaye’s dimension of type is focused only on users, different types of stakeholders were involved in our case, which is similar to previous studies (Byrne & Sahay, 2007; Puri et al., 2009; Johannessen & Ellingsen, 2012; Simonsen & Hertzum, 2012). The involvement of other external stakeholders, such as health service partners and donors, was also influenced by the relationships between the core organizations, i.e. the Ministry and the NGO. This confirms Johannessen & Ellingsen (2012)’s argument that

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<th>Content</th>
<th>Influence</th>
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<td>installation</td>
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**Table 2. Summary of Stakeholder participation**
participation is influenced by the mutuality of the relationships.

The degree of participation relates to the levels of responsibility assigned (Cavaye, 1995). In our case, the levels of responsibility were not explicitly predefined for all stakeholders involved, and we saw that they had varying degrees of participation at different stages (i.e. the extent). The users and managers assumed informative and consultative roles in the early stages of requirements analysis. However, during the coding and testing phases they assumed more decisive roles through their direct feedback on the software design. Hence, the degree of participation of users increased during the testing, deployment, and use phases. The managers were also responsible for approving the projects, and other design proposals that had implications at an organizational level, for instance, the task-shifting and introduction of visit summary printouts. In addition, the managers were responsible for identifying and informing participants about demonstration sessions and the training, which is similar to findings in previous literature (Avison & Fitzgerald, 2006; Bodker et al., 2004; Damodaran, 1996). Other external stakeholders, who were involved in the system reviews, also had decisive roles through their participation in the demonstrations. The designers had full responsibility for the projects, thereby assuming the ‘highest’ degree of participation and the ‘most’ extent of participation among the stakeholders. However, the designers also played a mediator role, which resonates with observations made by Johannessen & Ellingsen (2012).

The content of participation relates to whether users are involved in designing the social and/or technical aspects of the system (Cavaye, 1995). In our case, all the stakeholders involved (except for donors) contributed to the software design, which included defining data elements, data values, software logic, and interface design. This contrasts the recommendation that different types of ‘user groups’ should influence design aspects that are only relevant to them (Bodker et al., 2004; Damodaran, 1996). In our case, it would have meant that managers could only influence aspects of the reports, while end-users would influence the rest. It was different in our case since the data standards were defined at a national level by the ministry and its partners, and these standards included the data requirements even at health facility level. In this regard, the managers were able to explain the data requirements and the possible data values, which the end-users were unsure about. In addition, the stakeholders also contributed in defining the social aspects of the system, such as the service workflow.

The influence of participation represents the outcome of the participation (Cavaye, 1995), and is therefore linked to all the other dimensions. For instance, it can be assumed that when the degree of participation increases, the level of influence will follow suit. The areas of influence on the design are also closely linked to the extent and content of participation. However, not all participation resulted in specific design outcomes. Some of the design proposals were in conflict with other requirements and predefined design principles, which hindered implementation. For instance, it was not possible to allow editing of specific data elements because of the software logic. In this regard, the design alternatives were rather limited unlike most PD projects. Furthermore, we see that despite not being involved in the design process, the clients were an important stakeholder that influenced the definitions of the data and data values (e.g. in relation to capturing of the LMP date). The donors also influenced the scope of the projects that were undertaken, even though their extent of participation was minimal.

From our case, we see the importance of anchoring visions. This is proposed by Bodker et al. (2004) and relates to the involvement of other staff members during the design process. This proved to be important in our case, particularly during deployment and use of the system. The involvement of other healthcare workers who had previously not been considered, such as the HSAs, led to changes in work distributions and design of the software. In addition, once the system was in use, it became clear that it was important to involve other staff providing related services, such as HIV/AIDS testing, in order for them to adapt to the new workflow. We therefore argue that anchoring visions is an important part of the design process, especially when it goes hand-in-hand with difficulties of defining users, and in settings where work is highly collaborative, such as health care. Our case further shows that design does not take place at one particular stage of the development process, but rather occurs continuously throughout the process. In this regard, our case exemplifies a sustained PD approach recommended by Simonsen & Hertzum (2012).

In dealing with multiple stakeholders, Simonsen & Hertzum (2012) propose a strategy, which implies that by focusing on the involvement of the end-users, the interests of other parties will consequently be met. Our case, however, shows that focusing on the end-users’ work practices is not enough. In particular, the end-users at the rural health centers were not able to provide details on some of the data requirements. Thus, in addition to challenges with IT competence among users, as identified in other studies in developing countries (Elovaa et al., 2006; Kimaro & Titlestad, 2008), our study identifies another challenge: the limited expertise of expected end-users in the health domain area itself. This could be attributed to the human resource predicament in rural health centers, whereby they do not have the same access to highly qualified professionals as in urban areas. Furthermore, some of the expected end-users had not previously been involved in Antenatal care services and were therefore new to the domain area. Thus, in rural health centers or low-resource settings, the expected end-users may not always have the required specialized knowledge and, therefore managers and other health experts need to supplement this lack of knowledge.

CONCLUSION

In coming to a conclusion, we would like to reflect on a connectedness between experiences gained in the present design project and experiences reported from other PD projects (represented through related literature). While
PD aims at having users participate in decision-making throughout the process, the present study reveals variations in participation at different points in the development process. In addition, who the users are, is not consistent throughout the development process, but rather changes with the design. This requires a modus of flexibility that enables co-evolving of participation and the very design of the EMR.

Our analysis further sheds light on aspects of design work that stakeholders contribute to, which relate to both the social setting and the technical artifacts. In our case, the end-users were in the best position to define the social setting, and involving other staff (beyond end-users) proved invaluable for the process; however, managers’ approval was necessary in order to implement the proposed organizational changes. Furthermore, contrary to previous PD literature that argues for limiting managers’ participation; in our case managers had responsibility for defining data requirements. This supplemented users’ limited specialized knowledge in the domain area. This highlights the importance of leaving participation open for contributions from various stakeholders, considering their levels of expertise.

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Appendix 5: Paper 5

Challenges of Mediation in Global Software Development: Strategies for enhancing Participation

Tiwonge Davis Manda; Marlen Stacey Chawani; Caroline Ngoma.

Abstract

This paper reflects on challenges faced by the authors in acting as mediators between users in Malawi and Tanzania and global teams of software developers in a Distributed Software Development (DSD) project. We present a case on developing a generic free and open source software solution to support Antenatal care delivery in the two countries. The discussion centres on factors that challenged the authors’ participation in decision-making at global level, especially regarding the uptake of locally critical requirements. Our reflections centre on how the following factors accentuated various dimensions of exercising decision-making: geographical distribution of stakeholders, distribution of roles, flow of information, pragmatic of software development coordination, and software architecture. Based on identified challenges, the paper suggests a set of remedial complementary technical and organizational strategies that can be explored to enhance participation in DSD.

Keywords: Participatory design, distributed software development, mediation, decision-making power, strategy
Introduction

Participatory Design (PD) represents an approach towards computer-based systems development whereby future users of the system play a critical role in designing it (Schuler and Namioka, 1993; Bjerknes and Bratteteig, 1995). Traditionally, PD has been applied in small-scale projects where users and designers physically meet. However, networked technologies have enabled globally Distributed Software Development (DSD), allowing organisations to access technical expertise that is not locally available (Braa et al., 2004; Titlestad et al., 2009). Despite such benefits, DSD does make participation difficult (Blomberg and Karasti, 2012). For example, geographical distribution may make it difficult for users and software developers to meet, thereby significantly reducing possibilities for frequent discussions and feedback (Staring and Titlestad, 2008). Even where online collaboration tools are provided, target users might lack necessary communication infrastructure and IT competence, to inform software development (Farshchian and Divitini, 1999; Titlestad et al., 2009; Wubishet et al., 2013).

To enhance globally DSD, research proposes the use of mediators to facilitate communication, knowledge transfer, participation, and collaboration between stakeholder groups (Heeks et al., 2001; Lings et al., 2006; Tuovila and livari, 2007; Titlestad et al., 2009). Based on the diversity of roles they serve, several descriptions have been given about the mediator. For example, Heeks et al. (2001) describe mediators as straddlers who “have one foot in the client’s world and one in the developer’s world” (p. 59). The straddlers mediate the face-to-face interactions between users and developers. Mediators have also been referred to as boundary spanners who can span organisational and geographical boundaries (Sonnenwald, 1996; Barcellini et al., 2008a; Titlestad et al., 2009). Tuovila and livari (2007) describe mediators as bridge builders, who build communication linkages and provide two-directional feedback, between users and developers. In this paper we describe mediators as software implementers similar to the description presented in (Titlestad et al., 2009), who link developers at a global and local level, and healthcare providers who form the target user group. We view mediators as crucial stakeholders in facilitating PD in DSD.

Despite their relevance towards facilitating PD, the role of mediators is beset by various challenges, one of which is the lack of decision-making power to influence design decisions (Tuovila and livari, 2007; livari, 2011). Previous studies demonstrate that the involvement of mediators is often limited to providing requirements (informative capacity) and commenting on, or evaluating, outcomes of design decisions (consultative capacity) (livari and livari, 2006; livari, 2009; livari, 2011). Such inability of mediators to significantly influence design decision-making at global level might have profound implications on local development...
processes and relevance of developed software (Braa et al., 2004; Braa and Sahay, 2013). Thus more needs to be done in order to elucidate challenges mediators face in DSD and strategies that can be explored to enhance their participation.

In light of the above, this paper provides a reflection on challenges we faced in acting as mediators between a global software development team and users in Malawi and Tanzania. Our main focus is on development of DHIS Tracker solutions to support Antenatal care delivery in the two countries. DHIS Tracker is generic free and open source software for monitoring longitudinal provision of healthcare. The DHIS Tracker efforts reflected upon in this paper were part of a large action research project led by the Health Information Systems Programme (HISP), a global South-South-North network focusing on health information system strengthening in developing countries.

Our reflections centre on our involvement in decision-making at global level, in regard to the uptake of local software requirements. We reflect on how the following influence decision-making: geographical distribution of stakeholders, distribution of their roles, flow of information, pragmatics of software development coordination; and the DHIS Tracker software architecture. It is hoped that reflecting on challenges faced by mediators in regard to decision-making at global level and related implications on software development efforts at local implementation level will elucidate the intricacies of mediation and ways of enhancing participation in DSD. In presenting an account of our experiences, the paper also responds to a call for more accounts on the experiences of PD researchers in going about their work (see: Karasti, 2010). Karasti (2010) states that “the PD researcher remains the best kept secret, with scarce articulations of the associated roles, activities, skills, knowledge, agencies, relationships, and responsibilities” (Karasti, 2010: pp. 89).

Based on identified challenges, the paper also suggests a set of remedial complementary technical and organizational strategies that can be explored to enhance participation in DSD. The application of these strategies is perceived to open up the space for decision making. We discuss these strategies in more detail, as part of the literature review and discussion sections.

In the next section we present related work on participation in DSD projects. This is followed by a presentation of empirical material, findings, and discussion of the findings, respectively. Discussion of findings is followed by suggestion and discussion of the above-presented strategies.
Literature Review

In this section we review literature on the involvement of mediators in DSD and the exercise of decision-making power in participatory design projects. Focus is placed on personal and organizational attributes that form the basis for exercising decision-making power in software projects. Thereafter, we review PD strategies that have been employed to negotiate participation challenges in DSD.

Power and Decision-Making in PD and DSD

Often, design processes are permeated with values of utility and efficiency that compete with democratic ones (Asaro, 2000). Consequently, the sharing of power in PD is not straightforward, but requires negotiations of a complex interplay of mechanisms, which bring together different resources and multiple loyalties (Bratteteig and Wagner, 2012). Here power refers to the transformative capacity, i.e. ability to make a difference (Giddens, 1984: pp. 15) in the design and development of artefacts (Bratteteig and Wagner, 2012).

In trying to facilitate communication and collaboration between users and software developers, mediators often assume more specific formal roles, such as usability specialists, researchers, information managers, implementers (Iivari, 2009; Titlestad et al., 2009) or user representatives (Damodaran, 1996). Such roles have a bearing on mediators’ level of decision-making power and influence on the design process. Decision-making power is rooted in organization structures, such as hierarchies, which create challenges regarding project management, commitments, and requirements negotiation (Gumm, 2006). Software development projects are often structured around roles (Ye and Kishida, 2003; Barcellini et al., 2009). The distribution of roles is one key determinant of participants’ power positions, as it contributes towards the presence of hierarchies, determination of activities one can take part in, one’s proximity to the centre of decision-making, and overall influence on the community and software under development (Markus and Bjørn-Andersen, 1987; Nakakoji et al., 2002; Ye and Kishida, 2003; Staring and Titlestad, 2008; Barcellini et al., 2009). In the end, the ability of participants to exert influence on the development process reveals the degree and effectiveness of participation (Markus and Bjørn-Andersen, 1987; Cavaye, 1995; Bratteteig and Wagner, 2012).

Primary forms of exercising power within software development projects relate to access to information and position in the flow of communication within the network (Törpel et al., 2002), and having control over six elements:

(i) Material artefacts (Mahendran, 2002; Sack et al., 2006): These include key resources such as source code (Mahendran, 2002; Sack et al., 2006) and funding (Törpel et
al., 2002; Obendorf et al., 2009). For instance, powerful stakeholders may dominate the development of the software by offering to pay for specific developments (Obendorf et al., 2009). In addition, participants in open source software development may have different access rights to directly modify the source code (Xu and Madey, 2004; Barcellini et al., 2009).

(ii) Agenda formulation (Mahendran, 2002; Sack et al., 2006; Borum and Enderud 1981 - cited by Bratteteig and Wagner, 2012): The principal concern is who controls discussions (Sack et al., 2006; Bratteteig and Wagner, 2012).

(iii) Relevant technical expertise (Mahendran, 2002; Sack et al., 2006; Tuovila and livari, 2007): It is argued that individuals with programming skills, who contribute source code, retain considerable decision-making power compared to others (livari, 2009).

(iv) Implementation of consensus-based decisions (Barcellini et al., 2009; Bratteteig and Wagner, 2012): Where consensus building is required amongst stakeholders, decision-making power often lies with those responsible for implementing consensus-based decisions (Bratteteig and Wagner, 2012).

(v) Scope definition: This concerns the determination of which solutions are possible and which problems are judged relevant. Decision-making power can be exercised through decisions on who takes part in the various aspects of the software development process (ibid).

(vi) Enrolment of participants (Borum and Enderud 1981, cited by Bratteteig and Wagner, 2012): Hierarchical structuring of the participation space is often the case where users are not software developers and roles are differentiated between stakeholders (Staring and Titlestad, 2008; Braa and Sahay, 2013). Consequently, considerable decision-making power may often be restricted to members of the core software development team (Ye and Kishida, 2003; Barcellini et al., 2009; livari, 2009).

In DHIS2 development, Braa and Sahay (2013) highlight the presence of hierarchical organization of the participation space. They argue that “two levels of gate-keeping are required at the national and global levels possible through a certain level of dictatorship” (Braa and Sahay, 2013: pp. 247). Where key decision-making power is concentrated within the core team, the volume of traffic (communication, requirements, etc.) requiring the attention of the core team might increase response times to issues of local relevance.
In review elsewhere (Staring and Titlestad, 2008; Braa and Sahay, 2013). Consequently, hierarchical organization of the participation space might side-line mediators, thereby negatively impacting local engagement with users, as well as software development and customization work. For example, in participatory activities such as rapid prototyping, it might prove challenging to engage users and get necessary, at local level, where mediators do not retain sufficient decision-making power to push through requirement at global level (Staring and Titlestad, 2008). “Without a quick reaction to error reports and improvement proposals, users would not have the confidence that their feedback is taken seriously” (Hansson et al., 2006: pp. 6). Inability to foster local participation is also bound to have significant consequences at global level: “globally distributed solutions grow out of local designs and use, and DHIS2 as a global toolbox is utilised in local design processes. To what extent design is participatory will depend on how implementers mediate requirements between users and core developers” (Braa and Sahay, 2013: pp. 247). In addition, inabilities to foster local participatory processes might lead to a rise in parallel and competing software development efforts, also termed forking (Stalder and Hirsh, 2002), resulting in a duplication of efforts and possible incompatibilities between software versions (Staring and Titlestad, 2008; Titlestad et al., 2009).

In light of the above-presented challenges, we now review different strategies aimed at fostering participation in DSD. In going about the review we highlight strengths and limitations of the strategies.

**PD Strategies in DSD**

In this section we discuss the following strategies from extant literature: snowflake typology, inter-contextual user workshops, and commented case studies.

The snowflake topology entails the development of strong regional hubs that are in a better position to understand and address local concerns (Staring and Titlestad, 2008). This is aimed at taking pressure off core software development teams. The expectation is that such an organisation would decentralise decision-making and facilitate creation of user focused modules and can therefore balance global and local considerations (ibid.). The snowflake approach is similar to propositions by Törpel et al. (2002) to have distributed development processes organized as a continuous process of parallel experimentation and network-wide collection of experience, feedback, and integration into an overarching network-infrastructure, consisting of a variety of local substructures. This is particularly useful when stakeholders cannot meet to discuss design decisions, or available infrastructure does not allow for that to happen remotely (Törpel et al., 2002), or where core functionality is relatively
context dependent, but technical capacity is lacking in the local contexts (Staring and Titlestad, 2008).

A network of people travelling to collaborate is one of the salient features within snowflake topology. The circulation of researchers across and within countries has been the means with which learning, software and best practices have been spread within the HISP network, which serves as an empirical basis for the snowflake approach (Braa et al., 2004; Titlestad et al., 2009; Braa and Sahay, 2013: pp. 240). Despite its positives, a challenge with the snowflake approach is that it is bound to introduce new levels of mediation and inadvertently a more hierarchical organizational structure. Participatory strategies cannot reach far in a constellation where one organization dominates the scene and local decisions can be overruled by formally superordinate structures (Törpel et al., 2002). Influence of the dominant organization may be lessened by affording delegates of local substructures an opportunity to elect a committee that selects appropriate solutions, and providing for the negotiation of approval criteria (ibid). Aside from organizational setup, technical aspects of the software are key in enabling local participation. A modular software design is argued to enable more decentralised development of extensions by different people, to suit their needs (Benkler, 2002; Staring and Titlestad, 2008; Lawson et al., 2009; Wubishet et al., 2013). However, a basic challenge with this approach is the often high knowledge investment required to master software development frameworks and other technical tools in use (Titlestad et al., 2009). Thus, it is quite challenging to establish regional hubs.

Aside from the snowflake typology, inter-contextual user workshops and commented case studies (Obendorf et al., 2009) have been proposed as PD strategies to fostering inter-contextual community building, especially where users are distributed in different communities of practice. Inter-contextual workshops, which can be likened to ‘user meetings’ (Hansson et al., 2006), are aimed at bringing together, in face-to-face interaction, developers and users from different contexts. Inter-contextual workshops provide a platform for discussing use experiences and functional requirements for future development. On the other hand, commented case studies make face-to-face interaction persistent and permit ongoing exchange between users from different contexts. They are a written documentation of use experiences, describing the use and appropriation of software in different contexts in original user voices. They also document design decisions made by the developers in relation to indicated requirements. In this way, design decisions become transparent and enable users to gain insight about the guiding and underlying design principles.
The challenge with inter-contextual user workshops is that, as a consequence of their composition, discussions tend to be at a more abstract level and less context-specific (Obendorf et al., 2009). In addition, both inter-contextual user workshops and commented case studies are bound to leave key decision-making power in the hands of core software development team members who retain the power to choose contributors and participants, agenda items to be discussed, and implementation of consensus-based decisions. Reflecting on the functioning of ‘users meetings’, Hansson et al. (2006) state that users’ proposals for new functionality are ranked by developers according to their quality and relevance: "Is the change generic? How would it affect other functionality? Is it useful for many users? And how cumbersome will it be to implement the change?" (pp. 4).

In sum, DSD has provided new insights to traditional PD on how to involve local users in geographically distributed PD projects. Despite the strategies provided, the role of the mediator as a person who goes between the developers and the users remains challenging, when it comes to fostering participation while owning limited power to influence in making design decisions.

**Empirical Case and Research Methodology**

The paper provides a retrospective analysis of our involvement, as action researchers, in the development and customization efforts for DHIS Tracker; to support Antenatal care services delivery in Malawi and Tanzania. DHIS-Tracker is a generic software solution for collecting, managing and analysing transactional, case-based data records. It provides functionality for maintaining information about individuals enrolled under longitudinal health programmes, thereby allowing service providers to monitor access to services, over time. DHIS Tracker is a module within the DHIS 2 platform, a web-based solution for collecting, managing and analysing health data. The development of the DHIS 2 platform is coordinated by the Health Information Systems Programme at the University of Oslo (HISP Oslo). HISP is focused on designing, implementing, and sustaining Health Information Systems following a participatory approach to support local management of health care delivery (HISP, 2013).

DHIS Tracker development started in 2009 whereby the initial version was developed based on use cases from India. At this time, HISP India was at the heart of DHIS Tracker development efforts. In 2011, HISP Oslo took centre stage regarding coordination of DHIS Tracker development, with most of the development work being done by HISP Vietnam. The experiences chronicled here extended over the period July 2010 to December 2013, for Malawi, and November 2010 to March 2012, in the case of Tanzania. During this period, we were responsible for customising and implementing the DHIS Tracker in Malawi and

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Tanzania and acted as mediators between intended local users and the wider HISP network. A detailed account of these efforts is provided as part of the section on empirical insights.

**Research Approach**

In providing a reflective analysis of our involvement in the aforementioned DHIS Tracker efforts we attempt to fit ourselves in the text and examine implications of roles we assumed and our relations with others within the international HISP network. Engagement in reflective conversations of ones experiences can render alternative strategies for handling uncertainties faced in playing particular roles through questioning and articulating tacit assumptions associated with such roles (Bjørn and Boulus, 2011). Our reflections centre on two key roles we played, i.e. action researchers and mediators, with particular focus on how our connection to HISP Oslo, HISP India and HISP Vietnam influenced our performance of the roles. An assumption with playing the mediation role is that mediators are positioned such that they can ably influence decision-making in matters they mediate on. In addition, one main assumption in action research is that the researcher is supposed to have significant influence in the realization of solutions to identified problems that require intervention (see: Davison et al., 2004; Bjørn and Boulus, 2011).

In addition, our reflections are motivated by the first two authors’ involvement in another initiative where they collaborated with XYZ, an organization in Malawi, specializing in the development and implementation of an Electronic Medical Record (EMR) solution. Under this initiative, the second author was the project lead, making it possible for her to ably participate across software development stages and activities. The author was thus able to substantially contribute towards the development trajectory of the EMR software, through coordination of consultations with users, requirements definition, making design choices with the software developer, and software testing. Based on this, we sought to highlight what aspects of organization in the DHIS Tracker initiative constrained our participation. In addition, we sought to highlight implications of the extent of our participation at global level, on how we collaborated with local users, what software solution we were able to provide users, and related implications. Participation in workshops at local level, where we were often at the centre of coordination activities, and at international level, where other stakeholders took coordination roles, also helped use reflect on how roles we played shaped our influence on discussions at hand. Realizing that it is difficult to adequately provide an emic as well as an etic perspective, i.e. an insider and an outsider view (Holloway and Biley, 2011), we have also engaged extant literature on PD and DSD to learn from others and guide our reflections.
Nonetheless, the account presented here remains influenced by our perspectives and personal experiences.

At a more general level, we reflect on both opportunities and challenges we have experienced in our work. Such reflections are in part guided by discussions between us, as well as with colleagues involved in implementation work in Guinea Bissau and Uganda. Some of the discussions were audio recorded and transcribed, and form part of the material used in this paper. These discussions were useful because differences in the interpretation of phenomena of interest during group discussions are helpful in minimizing the bias of individuals (Wang and Hannafin, 2005; Bjørn and Boulus, 2011). As part of our empirical material we also draw upon email exchanges involving software developers. To an extent, these emails capture the voices of different stakeholders involved and detail: negotiations regarding local requirements; rationale behind choices made; time pressure to deliver on user requirements; and an ongoing dialectic between context-specific vs. global requirements and exigencies.

A more nuanced analysis of our data builds on Gumm’s (2006) definition of dimensions of distribution in software development which are: physical/geographical; organizational; temporal; and distribution of artefacts, skills, and other entities, among stakeholders. We focus on three dimensions: (i) organizational distribution around roles; (ii) geographical distribution, (iii) implications of the distribution of artefacts (source code) and skills among stakeholders. These are the dimensions we felt had the most influence on our work. On geographical distribution we mainly focused on how this impacted on acquaintanceship between stakeholders, our awareness of software development activities and who to communicate with, as well as the implications of such concerns on our work. Concerning organizational distribution, we decided to focus on how structuring of the local and global project contexts, especially in relation to how roles we assumed projected us either towards the periphery or centre of discourse and decision-making on requirement uptake and prioritization. Here, we were particularly guided by extant literature discussing implications of typologies of roles (Staring and Titlestad, 2008) on activities one can be involved in, as well as their proximity to the centre of decision-making (Barcellini et al., 2009). With the DHIS Tracker space organizational structuring in mind, we consider how the aforementioned dimensions of decision-making power were accessible to us and other relevant stakeholders. Finally, based on our experiences and reviewed extant literature we suggest a collection of methods that can help address identified challenges. In dealing with recommendations from literature, we have tried to examine what aspects of challenges we have identified suggested methods could address.
Empirical Insights: Distribution of DHIS Tracker Development Activities

Development of DHIS Tracker solutions for Malawi and Tanzania was a two part process starting with core software development by a global team of software developers, followed by customization of the software to fit local work practices and protocols for antenatal care delivery in the two countries. The two parts were geographically and temporally distributed, with significant parts of software customization taking place at local implementation level, in consultation with intended users (health practitioners).

In Malawi, the customisation effort began in July 2010 following a situation analysis that was conducted to identify information requirements for maternal health. This analysis involved interviewing health workers and managers in order to gain an understanding of maternal and child health work practices and data requirements. Based on the findings, the first two authors and a fellow researcher from Mozambique examined the DHIS Tracker software and began customization work on the software to fit the local maternal health work practices. Challenges faced in customisation (presented later on), coupled with school and travel commitments as researchers resulted in slow progression and eventually a halt in the DHIS-Tracker customization efforts. The customisation efforts were revived in March 2012 and involved designing data entry forms for antenatal care visits and the required monthly cohort report. During the customization process, the software was demonstrated and tested by expected users at the planned implementation site in order to evaluate interface designs. After further customisation, training of the expected users was conducted over a period of 5 days at the health centre. Customisation and software installations continued after the training and the system was deployed for use at the health centre in November 2012. This was then followed by support visits that allowed evaluation of the system in use.

Customisation efforts in Tanzania commenced in November 2010. Requirements that were used to adapt the DHIS Tracker were based on a situation analysis conducted by the third author. During this time, DHIS2 was being rolled-out throughout the country by a local team of developers, in collaboration with the Ministry of Health and Social Welfare. In customisation of the DHIS Tracker, the third author worked with one local DHIS developer whose roles included DHIS Tracker programming and ensuring that all work done in relation to DHIS Tracker was in synch with overall DHIS2 development efforts in Tanzania. Tanzania had a local DHIS2 development branch. Customisation efforts mainly centred on database and interface design. The local customisation process was constantly challenged by the need to understand local work practices and requirements, on the one hand, and collaborating with the global development team, to negotiate the incorporation of urgent local requirements into the DHIS Tracker core, on the other. At local level, meetings with, and

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training of, intended users provided important avenues for obtaining and deliberating more concrete requirements to guide local software development and customization. In March 2011 the third author facilitated DHIS Tracker training for target users, after which DHIS Tracker was installed to be used in one health centre. Use of the software resulted in additional requirements that required incorporation into the software’s design.

At global level, core software development involved gathering and prioritising requirements from different countries and stakeholder groups, software coding, release of new versions of the software and its evaluation. We were involved in evaluation of the DHIS Tracker, either as part of our customization and implementation work in Malawi and Tanzania, or as part of international workshops and meetings on DHIS. We participated in six DHIS workshops, of which four were implementers’ training workshops and two were general workshops. We also participated in four meetings, one of which was a design meeting on DHIS Tracker, and one was a DHIS launch meeting. The other two meetings were focused on research topics in relation to the DHIS Tracker implementations. Figure 1: presents a summary of the DHIS Tracker core development and customization efforts.

![Figure 1: DHIS Tracker development activities](image_url)

The organisation/distribution of the core software development activities during the early stages when HISP India was at the centre of the development, differed from the period when HISP Oslo was coordinating the development. We present these in the next two sub-sections.

**HISP India-led DHIS-Tracker Development: Geographical Distribution and Information Flow Challenges**

During the initial customisation efforts of DHIS Tracker in Malawi, our team noted that the software did not support some of the local requirements. For example, there was need for sharing of some data elements, such as a mother’s HIV/AIDS status across health
programmes, which was not supported by the software. At this time, HISP India was at the centre of software development. At this stage, support processes were poorly developed, which made our work at local implementation level quite challenging. Below is an extract of a discussion between the authors, held in August 2012, which details challenges we experienced. The conversation covered a recollection of past experiences as well as contemporary issues at that time.

T: …in terms of, let’s say, the information on the milestones for development or incorporation of requirements from these implementation sites, how are things like?

C: I think there is no standard way or formal way of how we communicate because somehow they don’t even know what we are doing there, what we are not doing, and we also don’t know what they are doing [and] what they are not doing. So like when there is a problem, we report to F1 [a coordinator from HISP India]. F1, maybe, will report to someone else or maybe work on it, and come back to you.

M: Why F1?

C: F1 is the connection that I know.

T: So the chain, is also not that visible… the chain of participation…anything else, in terms of … support manuals, like documentation?

C: Like for me I haven’t had any… All the support I get is [from] my own effort[s] to know this and how I can go about this but most of the support I get is from local teams, maybe you, F2, but not [core] developers directly.

T: Okay, M what is your experience like?

M: I’d say the same thing. Like I haven’t really been interacting with the core developers.

T: Okay and what are the implications of that, in terms of your work?

C: … Sometimes you want to do something [and] it’s not possible… but when you ask them, they had already upgraded the system. [They say] Oh! You can do this… upgrade and then it will be possible. You don’t know where the development is [and] at what stage.

T: Alright, yeah [be]cause I think it has been like that for some time because I remember, over the weekend, I was having a discussion with F2, so he was saying there was one feature … that everyone here [in Oslo] didn’t know how to get done. I think there was some workshop and F1 was not around in the first day, people were discussing that issue and said: ah no! This can’t be done, so let’s flag it as a feature that needs to be developed. Then, F1 showed up the next day and said: no! This can be done; this is what you need to do. So, I think with this sort of PD, where you are not fully in control, I think access to the information, then, is key.
From the conversation it can be noted that support processes such as documentation and capacity development plans for implementers were not well developed. The discussion also reveals compatibility issues across software versions, which made migration difficult. At this time, having good communication links with the main developers and other people with better knowledge of the software was therefore critical. However, it proved difficult to communicate and get the required functionality incorporated in DHIS Tracker. Our challenges were also heightened by the fact that HISP Oslo which was supposed to function as a hub between HISP India and international researchers and implementers, and to whom we were better linked, also did not have sufficient knowledge on the workings of DHIS Tracker. HISP Oslo’s lack of consistently up to date information on developments in India negatively impacted their role as mediators, which in turn had a negative impact on our work. Consequently, communication of requirements and solicitation of necessary technical assistance was reliant on hard-to-come-by personal links with members of the software development team in India. From the core DHIS Tracker development team in India, the authors were conversant with only one coordinator (labelled F1 in the conversation above).

**HISP Oslo-led DHIS Tracker Development: Distribution of Roles and Power Asymmetry Challenges**

At the time efforts to customise DHIS Tracker in Malawi were revived, HISP Oslo was coordinating the development of the module. The bulk of core DHIS Tracker software development was done in Vietnam, but under the watch of HISP Oslo, who were responsible for assigning and monitoring software development tasks. To coordinate global software development, activities in HISP Oslo are in general structured around roles such as: software developers, implementers, documenters, and coordinators. Individuals can mix multiple roles, but certain roles are often personalised. Adaptation of DHIS software to fit local requirements is often done by implementers, who are also often involved in research. Coordination roles also have dedicated people, even though coordinators may also be involved in software development, implementation, or research. Coordinators and some lead software developers are mainly responsible for coordinating requirements gathering, prioritization, and assignment of work tasks to developers such as those in Vietnam. They are also responsible for coordinating communication forums such as conference calls and international workshops. The recognition of roles is visible in the structuring of the DHIS2 collaborative space, through mailing lists, calls for workshops, and personalization of roles by individuals as demonstrated in the quotes below.

“You are welcome to join our upcoming DHIS 2 training at the HISP Lab in HISP Oslo … We have called the training: "Advanced Implementer Training and Introduction to
DHIS 2 development …the days we’ll split into implementer and developer tracks. Developer track will be introduction sessions for the new developers” (Email communication - Coordinator HISP Oslo, 2013)

“We are not developers; we are implementers... Developers are V and those kind of guys...developers are those who do hard-coding, inscribing users' world views into the software. Then, there are those of us [implementers] who help by bridging the gap between those [software developer] in HISP Oslo and those [stakeholders/users] back home [in Africa]” (Personal Conversation -Implementer, 2013).

With the coming to prominence of HISP Oslo, there was a reduction in the communication distance between us and the personnel coordinating software development. As researchers based in Oslo, we were well acquainted with members of HISP Oslo. However, having HISP Oslo as the coordination hub meant that they were very much the gatekeepers with regard to what requirements were taken on board or not. Prioritization of requirements was necessary to filter generic requirements from those that were rather more context-specific. In general, requirements in the DHIS community are gathered and discussed using multiple communication channels including conference calls, email, and international workshops. In addition, functionality blueprints are submitted through Launchpad, a software collaboration platform, and one-on-one consultations with coordinators.

Though mostly functional, an inadvertent consequence of the above-presented setup is that it can be quite challenging to push through context-specific requirements into the global core. This is because decision-making on the uptake of requirements seems to favour those acting as gatekeepers. We faced challenges in trying to push through requirements for generation of aggregate reports from the two countries. For example, a key requirement for the implementation in Malawi was generation of a cohort-based report to monitor ANC service delivery. Generation of a cohort report demanded aggregation of data for services provided across a seven-month period, for a group of women who started accessing ANC services in a particular month. Although ANC was a common use case within DHIS Tracker implementations and the software provided for a query builder, the design of cohort-based reports was not provided for. Figures 2 through 5 depict extracts from an email thread between the authors, colleagues from Mozambique, a coordinator from HISP India and two DHIS Tracker developers based in Oslo and Vietnam, regarding the cohort report.
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Dear all,

we need help on how to do a cohort report for ANC clients in NBHTS/DHIS2 Tracker, for Malawi.

Here is the tricky bit that we are struggling with - A report for the current month is supposed to aggregate data for people who had there first visit 7 MONTHS ago, i.e a report for March 2012 should aggregate data for clients who had their 1st ANC visit in September 2011.

For example, the data element on the form "Tot with 1 visit" should show how many women had a total of one visit out of those who started in september 2011.

I have attached a copy of the reporting form in use, for your reference.

Is there a way of getting this done in DHIS Tacker?

Our implementation for in Facility service delivery is heavily dependent on getting this done.

Kind Regards

---

Figure 2: Query on possibility to generate cohort reports

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Figure 3: Response detailing how to use existing functionality

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Figure 4: Providing clarification on query
Figure 5: Confirmation that cohort reporting was not possible

The discussion ended without a conclusive indication on the way forward. As a result, we implemented the system at the health centre without functional report aggregation. The reporting requirement was later presented to HISP Oslo coordinators during a DHIS Tracker workshop and the criticality of the requirement was noted. However, it was noted that further action required wider consultations with other stakeholders to avoid tying down functionality in DHIS Tracker to individual implementation contexts. Our team was advised to work with another a colleague within HISP Oslo, who was doing similar research and implementation work in Ghana, to identify how to address our requirements. As a work around, custom SQL scripts were developed to support generation of the cohort report. Development of the SQL scripts required in-depth knowledge of the DHIS Tracker database structure and was more of a hack in that the scripts were greatly tied to unique data field identifiers within a specific database. Consequently, considerable manual work would be necessary to replicate the solution under a different database.

The inability to implement the reporting functionality was also a concern to users. During a field visit to the health centre, by the second author, users reiterated the need for reports as demonstrated in the quote below:

“I feel like we are just playing on the computer. Because we are just entering, and entering [data], there is nothing like this one has delivered, they are just still there, there is nothing for us to see how many people we have this month, what are you saying about the reports?” [Health worker – Review meeting, August 2013]
Reporting functionality was also important in the case of Tanzania. However, in this case, the organisational arrangement was different as a local developer was available.

**Pragmatism and Coordination: Challenges of Local Development with a Global Software Project**

Engaging a local developer allowed for quick realization of some local requirements and partially reduced the time lag in implementing locally relevant functionality. However, software enhancements done at the local level were diverging from the global development, making it difficult to get support and software updates from the global development. To avoid operating as a single node, local development work had to stop and follow directives from the global team. In this manner the required functionality for generating aggregate reports could not be developed at the local level, not because of lack of technical capacity but, to avoid forking. This functionality was very useful for the health workers who indicated that manual compilation of aggregate reports was laborious and time consuming. Although it was indicated to users that the required functionality would soon be available, collaboration with the global developers was imperative for this to happen. Below (figures 6 and 7) are some email conversations between the local developer, the third author, and the global developers, regarding implementation of functionality for producing aggregate reports. The emails demonstrate tensions between creation of a separate locally controlled DHIS development branch, in order to gain more control in addressing local requirements, but risk isolation from the global team, and sticking with the core global development branch, to benefit from developments at that level.
The following email was a reply from the local development team to the global developer’s email, indicating an urgent need to incorporate local requirements in DHIS Tracker.

On 1 Aug 2011 22:06, 12@gmail.com wrote:
I concur with you on the matter, we’re most likely to face these setbacks in near future. I am aware that is currently making further developments on the patients module, we however have set of requirements and deadlines specific for Tanzania which may also be beneficial to whole community, among the requirements includes:

Reports:
1. Programs: Excel reports for all patient data captured on all program stages
2. Calculated Excel reports from patient based data captured
3. Scheduled Visits: Excel reports for all patients registered in provided program.

Patients module only have summary reports which have no way of getting them out to a document except by saving a webpage, Import/Export.
Currently there’s no way of exporting and import data which force us to resort to postgres backups and this severely impacts data quality check and follow ups on supportive supervision.

Mobile support:
1. Sending educational messages to clients attending a program
4. Sending messages to clients on date of next scheduled visits

Danger signs:
Warning notifications to Doctors/Nurses in case of danger signs shown by previous visit data so extra caution can be taken,
And Beneficiary registration should be in the services rather than maintenance.

So currently core patients module is insufficient to cover all these requirements, and these features are highly needed by facility nurses on Miccani Health Center. Correct me if I’m wrong the benefit of developing on local branch is that we don’t affect the core DHIS development and core DHIS development don’t affect our local development, same reason we did migrate import-export for human resource from core import-export back to local.

One way did suggest dealing with this issue when we were dealing with import-export for hr) was writing patches for all the code changes which we would apply when we want the features being part of the core DHIS, we however can’t build all these features through running patches, and reverting core DHIS changes every time we commit,

So if there’s a way to achieve this without either affecting development of core DHIS or impede development of local DHIS I’m more than glad accept.

Looking forward to hear from you.

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These email exchanges did not yield much. The global developers recommended an upgrade to a newer version which the developers indicated would address the issues raised. However, the said version had no backward compatibility, requiring the Tanzanian team to recreate its DHIS Tracker database, as well as manually migrate data from the software version in use to the new version. In the meantime the users were urged to be patient about the report functionality. In the end, the new version did not help either so another request for implementation of required aggregate reporting functionality was sent to the global developers.

The emails below show (figure 8 to 12) correspondence between the team in Tanzania and core DHIS Tracker developers, where the Tanzanian team sought help and clarification on the query builder in DHIS Tracker. The emails demonstrate multiple levels of mediation and embodiment of decision-making power stemming from the organization structure under HISP Oslo.

Figure 8: Challenges with DHIS Tracker query builder

Figure 9: Directions on where to access help
Following the instructions in the user guide provided, did not resolve the report generation. We contacted the global developers again.

Hi et al,

Thanks for your earlier inputs into the aggregation query builder, I have Two Questions for now.

Are there any plans soon to implement import export for patients module, like import export for aggregation query builders, programs, programstages, etc., I was looking forward to it,

Figure 10: Request for data export module

Hi

Please see below :) 

On Mon, Nov 14, 2011 at 9:07 PM, wrote:

Hi et al,

Thanks for your earlier inputs into the aggregation query builder, I have Two Questions for now.

Are there any plans soon to implement import export for patients module, like import export for aggregation query builders, programs, programstages, etc., I was looking forward to it,

I will propose this function with now, if he says YES, I can start it and inform you when I finish :)

Figure 11: Indication that HISP Oslo had to decide on inclusion of requirement

On Wed, Nov 16, 2011 at 9:18 AM, wrote:

hi

Below is response for Import/Export function :)

------- Forwarded message -------

From: @gmail.com>
Date: 2011/11/16
Subject: Re: Aggregation Query Builder
To: @gmail.com>
Cc: @gmail.com>

Hi all, we must wait a bit with this now - we are currently re-writing the whole import-export module to make it more robust. Yes it would be good to have import of these things but lets come back to it later.

Figure 12: Pending of data export functionality
Waiting was the last thing the users wanted to hear because at this time, they had been entering data for 9 months without being able to print reports.

The third author’s role as a mediator was challenged especially in maintaining the trust of users, when she was unable to influence decision-making concerning what features needed to be prioritised by the global developers in the system development. Even though the users gained advantages through using other features of the implemented system, absence of the reporting functionality stalled them from entering data into the system.

Challenges arising from local modification of DHIS2 software tools are not uncommon. Over the years, developers working in India, Ethiopia, and Vietnam have modified the core of the DHIS2 tool suite to respond to local needs. The challenges documented in prior studies (Staring and Titlestad, 2008; Titlestad et al., 2009) include incompatibilities in local and global software versions, as well as the difficulty of pushing local software enhancements to the global level.

**Software Architecture and its Influence on the Distribution of Decision-Making Power**

To an extent, local software development efforts in other DHIS software modules, such as DHIS2 Aggregate, have benefited from the presence of more developed Application Programming Interfaces (APIs). DHIS2 Aggregate provides functionality for managing aggregate data. DHIS2 Aggregate attracted more complementary extensions that were either integrated into the global core or were only in use at local level. For example, developers in India have over the years developed extensions solely for their use context. Another developer based in Zambia also developed custom extensions, using the R programming language, to generate statistical analyses that were not possible using DHIS Aggregate.

Version 2.13 of DHIS, released in September 2013, also introduced an app store, which allows third party software developed using HTML and JavaScript to be installed inside DHIS2 software. Providing for development in HTML and JavaScript lowers technical requirements for developing extensions to the DHIS 2 tool suite. However, at the time of writing, DHIS Tracker was yet to benefit from such developments due to its largely missing API. Consequently, significant enhancements had to be made to the software core, under the coordination of HISP Oslo. In addition, the level of DHIS Tracker maturity resulted in challenges regarding software compatibility across versions, for instance, the lack of functionality for patient data import and export (see figure 12).
Discussion

In this section we discuss how geographical and organizational distribution of stakeholders and activities, as well as DHIS Tracker architecture, influenced our decision-making power in regard to the prioritization and implementation of requirements. This discussion is built on identified dimensions of decision-making power, which include: level of technical expertise; access to information and position in the flow of communication within the network; control over material artefacts (source code); agenda formulation; implementation of consensus-based decisions; and scope definition. This discussion is followed by suggestions of technical and organizational strategies that can be employed to enhance participation.

Mediation and decision-making power

The empirical account suggests both the necessity and difficulty of mediation in trying to foster PD, where software development activities are both geographically and organizationally distributed (around roles). Mediation was necessary to allow for local collaboration with users (health practitioners) and access to necessary domain knowledge, as core developers and users were never in contact. Thus, we communicated local requirements to the global team and customized DHIS Tracker to fit local requirements. The DHIS Tracker implementations in Malawi and Tanzania, presented herein, would not have been possible without our involvement. Various studies underscore the criticality of mediation within geographically distributed software projects, in general (Herbsleb and Grinter, 1999), and DHIS-related software projects in particular (Braa et al., 2004; Staring and Titlestad, 2008; Titlestad et al., 2009; Braa and Sahay, 2013).

Having established the criticality of our mediation to the DHIS Tracker efforts in Malawi and Tanzania, it is worthwhile reflecting on the nature of our involvement, together with its implications on local software development and customization efforts. A previous study on distributed DHIS-related efforts states that “to what extent design is participatory will depend on how implementers mediate requirements between users and core developers.” (Braa and Sahay, 2013: pp. 247). In addition, other studies argue that mediators can be more effective if they significantly contribute towards design related decision-making (Iivari, 2009). In our case, our involvement in DHIS Tracker development at global level was mostly informative and consultative in nature, rather than decisive. We mostly contributed towards communication of local requirements and evaluation of software design.

Extant literature demonstrates that although PD aims to broaden participation in decision-making power asymmetries are not alien to PD processes (Iivari, 2009; Iivari, 2011;
Bratteteig and Wagner, 2012). Often, obstacles to participation are embedded in prevailing institutional constructs (Grudin, 1991). Two key contributing factors that impeded our participation in decision-making at global level were increased communication distance with key stakeholders (implementers, core developers, coordinators), and hierarchical structuring of the DHIS Tracker project space, around roles. With regard to communication distance, it was challenging to communicate and follow up on requirements, during the time HISP India was leading software development efforts. A major contributing factor was our lack of adequate awareness regarding organizational structuring of the DHIS Tracker project space, especially whom to communicate with. One fitting example of this is the lack of synchronization in local and global DHIS Tracker development efforts, as is evidenced in the following statement: “You don’t know where the development is [and] at what stage” (see conversation in findings). The slow progress in software customization and implementation that ensued from this lack of clarity is reminiscent of observations from previous studies, which argue that increased communication distance increases software development cycles (Staring and Titlestad, 2008). In addition, access to information and positioning in the flow of communication has been noted as a determinant of how much control stakeholders can exert on developments at hand (Törpel et al., 2002).

Use of personal links to access necessary technical support did offset some of these challenges, to an extent:

“All the support I get is [from] my own effort[s] to know this and how I can go about this but most of the support I get is from local teams, maybe you, F2, but not [core] developers directly” (third author – see conversation in findings).

An interesting aspect of these developments is the ability of different mediators to leverage each other’s skills in order to make up for the gulf in communication with core team members. Beyond mediator-to-mediator collaboration our increased awareness of DHIS Tracker development processes after the coming to prominence of HISP Oslo, with whom we were well acquainted, highlights the significance of communication distance. This said, the nature of participation is not only subject to one’s communication distance from key decision makers, but also organizational distribution of roles (Ye and Kishida, 2003; Gumm, 2006; Barcellini et al., 2009).

Hierarchical organization is often the case where there are multiple levels of mediation (Staring and Titlestad, 2008; Braa and Sahay, 2013) and distribution of development activities around roles (Gumm, 2006; Barcellini et al., 2009). As presented in the findings, the
DHIS project space is structured around roles: developers, implementers, coordinators. In the presence of hierarchies, design decision-making, often favours members of core software development teams (Barcellini et al., 2009) and might push mediators, who are not contributors of source code, towards the periphery (Iivari, 2009). In light of our empirical account, it is evident that we were very much on the periphery in the consideration of software requirements at global level. By coordinating various communication spaces for gathering requirements (mailing lists, conference calls, international workshops, etc.) HISP Oslo retained considerable control over agenda formulation and the trajectory of discussions. Furthermore, in a setup where requirements from different use contexts were in conflict at times and required prioritization, HISP Oslo retained control over scope definition, through determination of which requirements were judged relevant. Our inability to push through requirements for report aggregation functionality, despite their criticality to DHIS tracker implementation in Malawi and Tanzania, serve as examples. Having oversight of the implementation of consensus-based decisions from conference calls and international workshops, through coordination of software development activities, also enhanced HISP Oslo’s position at the heart of decision-making.

Despite such challenges, steps taken by the third author in engaging a developer at local level can be seen as a way of strengthening her position as a mediator, as this afforded her an increased level of control over the implementation of context-specific requirements. Collaboration between the first two authors and another colleague, to develop custom SQL scripts for cohort-based reporting, can also be seen in the same light. This notwithstanding, these efforts were not without challenges. For example, stakeholders in Tanzania stood to lose support of the global by forking the DHIS development branch (see figure 6). However, in staying as part of the global DHIS core branch, local efforts stagnated at some point. A case in point is suspension of work on the DHIS tracker import and export function (see figure 12). Inasmuch as DHIS Tracker is open source software it can be said that HISP Oslo retains significant control of the source code, especially where stakeholders want to benefit from global development efforts.

Control of material artefacts such as source code has been documented as an arena for exercising decision-making power (Mahendran, 2002; Xu and Madey, 2004; Sack et al., 2006). Limitations in DHIS Tracker software architecture, especially underdevelopment of DHIS Tracker’s application programming interface (API) also lowers possibilities for making significant loosely coupled extensions to the software. This, then, further consolidates HISP Oslo’s position at the centre of decision-making, since any significant changes need to be made to the software core, which it is in charge of. Modular software architecture, with well-
developed APIs has been noted as a key enabler for decentralization efforts to extend software (Benkler, 2002; Lawson et al., 2009; Wubishet et al., 2013). Even so, dominance of a single player in the network can be problematic, as has been noted by previous studies (Törpel et al., 2002; Staring and Titlestad, 2008). Modular architecture might provide the technical basis for extended software development efforts at local level, but the prevailing organizational setup influences what gets integrated into the global core (Staring and Titlestad, 2008; Titlestad et al., 2009). In the end, the organizational setup is such that as mediators with no software development and implementation roles at global level, our place was at the periphery of key decision-making, which negatively impacted the continuity of participatory processes at local level.

The effectiveness of participatory processes such as the action research methodology we adopted requires demonstrable progress in the actualization of user requirements. Attainment of such objectives can be quite challenging where mediators lack technical skills to implement such functionality themselves, and lack sufficient proximity to the centre of decision-making. The disillusionment expressed by users in Malawi with regard to missing functionality for cohort-based reporting serves as fitting examples of how participation challenges at global level can impact local implementation efforts. Next, we discuss various technical and organizational-centred strategies that can help decentralize decision-making, along with related limitations. The methods discussed are based on our experiences and reviewed literature.

**Suggested Strategies and related limitations**

Organizational strategies discussed in this section include: workshops, voting on functionality, functionality blueprints and roadmaps, commented case studies, travelling core software development team members, and building local software development capacity. Proposed technical measures include: promotion of modular software architecture and progressing beyond development of generic software, to be adapted by local implementers, to offering application platforms.

International workshops, also termed inter-contextual workshops (Obendorf et al., 2009), allow for some level of negotiation, detailed communication of requirements, and development of acquaintanceship. Such interaction goes some way in shaping the uptake of requirements (Braa et al., 2004; Staring and Titlestad, 2008; Obendorf et al., 2009). Although in our case such workshops did not necessarily result in the uptake of key context-specific requirements, we did benefit from some level of acquaintanceship developed. The aforementioned development of custom SQL scripts for cohort-based reporting is an
example of such. Through this collaboration we were able to sidestep the organizational bureaucracy involved in trying to push through requirements for inclusions in core DHIS Tracker development.

By enabling stakeholders from multiple contexts to engage, inter-contextual workshops may also provide an opportunity for participants to speak with a unified voice on functionality of common interest. When speaking with a unified voice, participants in DHIS Tracker workshops may considerably influence decision-making concerning what problems are deemed relevant (scope definition (Bratteteig and Wagner, 2012)), as well as how consensus-based decisions are implemented. This would addresses the concern that implementation of consensus-based decisions might concentrate decision-making power in the hands of a few (see: Bratteteig and Wagner, 2012). To further strengthen participation, and lower the concentration of decision-making to within core software development team, we are of the view that international DHIS Tracker workshops may also benefit from affording participants voting rights, to determine the relevance and criticality of proposed functionality. Taking such a step would make decision-making less centralised, thereby allowing mediators such as us to have increased influence at global level. Voting has been used in various software development projects to guide and broaden participation in decision-making, especially regarding controversial topics (Fielding, 1999; Erenkrantz and Taylor, 2003; Barcellini et al., 2008b; Ko and Chilana, 2010). However, previous studies note that binding voting rights are often restricted to members of core development team (Fielding, 1999; Erenkrantz and Taylor, 2003). We argue for the broadening of voting rights beyond members of core development teams, to increase the decision-making power of mediators outside the core development team.

A challenge with voting is that it might require participation in online collaborations. However, we have observed, from personal experience and extant literature, that it is not always possible for all stakeholders to participate in all required online collaboration (Titlestad et al., 2009; Wubishet et al., 2013). Where stakeholders are not part of the decision-making process, transparency on decisions made might prevent disillusionment on their part. In our case, documentation of functionality blueprints and a roadmap of software releases at least created an awareness of what was possible within a set period of time. The only challenge with the setup was that the rationale behind choices made and related activity planning was seldom visible. Therefore, providing for voting on prioritization of functionality (scope definition) could also enhance the visibility of rationale behind choices made. In addition to voting, the use of commented case studies provides another way of enhancing transparency, through documentation of use cases and experiences, and design decisions made by the
developers (Obendorf et al., 2009). The richness of commented case studies could also make up for the lack of clarity on context specific requirements. Despite the time investment required to develop commented case studies, the DHIS network has sufficient human resources to actualise this, considering that it is an action research network with a growing number of researchers managing local implementations. For example, we are researchers documenting development activities.

Finally, to complement possibilities offered by the strategies above, it might still be necessary to have members of the core software development team travel to particular contexts, where possible. Immersion in implementation contexts can allow for a deeper understanding of users, complex local dynamics and requirements, through first hand experiences. In addition, previous studies on DHIS-related software development demonstrate that core DHIS developers’ travel to implementation sites promotes local software development expertise and participation, through rapid evolutionary prototyping in consultation with local users and developers (Staring and Titlestad, 2008; Titlestad et al., 2009). Despite such benefits, it is worth pointing out that travel of core team members to particular implementation contexts should be approached with caution. If not well managed, it may heighten dependence on the central node. In addition, the travel of core development team members might elevate requirements from contexts they travel to, at the expense of others. For the long-term, efforts to increase local software development capacity, in addition to existing efforts on developing implementation competence, could help thrust local software development efforts and the snowflake typology, suggested by Staring and Titlestad (2008), forward.

In terms of the technical aspects, design elements such as APIs and the application store (App store) employed in DHIS2 Aggregate can lower current barriers to extending DHIS Tracker, through decoupling local software development efforts from those at global level. There are indications from DHIS Aggregate software development efforts and extant literature that having a well-developed API attracts development of complementary functionality, for the benefit of both context-specific and global software development efforts. Furthermore, a shift from exclusively offering a customizable software product to providing an application platform, as is increasingly becoming the case with DHIS2, can further decentralize design decision-making. Although not currently at the core of PD literature, offerings such as Apple’s iOS, Google’s Android OS, and Windows Mobile demonstrate the relevance of mature APIs, application platforms, and app stores in encouraging parallel software development efforts, to fit local requirements, in a way that benefits both local and global user communities. Figure 13 depicts a collection of organizational and technological
strategies discussed herein, as pieces of a jigsaw puzzle to further participation within DSD efforts.

These strategies are complementary as they address different aspects of the aforementioned forms of exercising decision-making power in software development efforts. More specifically, implementing technical solutions such as APIs and App stores address challenges of control over material artefacts, i.e. source code. They also provide room for local control of the scope definition. For example, application platforms afford distributed stakeholders more control in deciding on solutions that suit local needs, whilst also benefiting from global software offerings. In this way, there is bound to be reduced coupling between global and context specific software development efforts. The use of mature APIs and affording the installation of third party applications developed using HTML and JavaScript also significantly lowers the level of technical skills required for one to contribute to DHIS software development. Related to this, in affording increased local participation is the software development process we can in part lessen the effects of geographical distribution of stakeholders and the amount of decisions made by the central node (Staring and Titlestad, 2008).

Approaches such as commented case studies (Obendorf et al., 2009), workshops, functionality blueprints and roadmaps seek to address challenges that relate to information flow, by making documentation of requirements and related decision-making more transparent. In this way, these approaches also serve to facilitate software coordination. A combined use of workshops and voting on functionality may also serve to open up the space for exercising decision-making power, thereby lessening the effect of hierarchical structuring
around roles. Development of local software development capacity is necessary to reduce
dependence on a single central node, and consequently the time lag in trying to address
context-specific requirements (Staring and Titlestad, 2008).

Conclusion
This paper provides a reflective analysis of our participation, as PD researchers, in a globally
DSD project. We acted as mediators between users in Malawi and Tanzania, and software
development teams in Norway, India, and Vietnam. Our findings reveal that, as mediators,
our participation was more informative and consultative rather than participative. We had
limited decision-making power regarding prioritisation and inclusion of local requirements in
the software under development. Our reflections centre on how the following factors
influence decision-making: geographical distribution of stakeholders, distribution of roles,
flow of information, and the DHIS Tracker software architecture. More specifically, we have
considered how these factors accentuate the following dimensions of exercising decision-
making power: level of technical expertise; access to information and position in the flow of
communication within the network; control over: material artefacts (source code); agenda
formulation; implementation of consensus-based decisions; and scope definition. While other
studies have similarly identified lack of decision-making power among mediators (Iivari,
2009; Iivari, 2011), the implications and consequences of this on local software development
efforts have seldom been analysed. Our cases demonstrate how such lack of decision-
making power can weaken the effectiveness of participation and negatively influence
progression of local implementations. In our cases, incomplete solutions were implemented
that did not meet requirements important to the users, and this was frustrating for us and the
users.

Addressing the observed challenges is not an easy undertaking. Previous studies
demonstrate that the sharing of power in PD is not straightforward, but requires negotiations
of a complex interplay of mechanisms, which bring together different resources and multiple
loyalties (Bratteteig and Wagner, 2012). We observe that suggested PD strategies for
enhancing participation in DSD only address parts of the dimensions of exercising decision-
making power outlined here. Despite this, there is a scarcity of literature which examines
strengths and limitations of applying a combination of complementary PD strategies which
can collectively address the above-mentioned dimensions for exercising decision-making
power, in order to enhance participation. This is the gap this paper attempts to address.

We advance a combination of technical and organizational strategies that would enhance
participation of stakeholders, within DSD projects. The strategies we suggest are drawn from
extant literature and empirical insights. Suggested strategies are aimed at promoting sharing of power across the identified dimensions for exercising decision-making power. Suggested technical strategies centre on modular software architecture and include pushing for mature application programming interfaces, as well as moving from development of customizable software packages to application platforms and stores, in a bid to open up and decentralise software development.

Suggested organizational strategies include: workshops, to bring together stakeholders and discuss requirements and design decisions, and commented case studies, functionality blueprints, and roadmaps, to document use cases and uplift common requirements. We also propose: allowing for voting on functionality, to broaden participation in decision-making; local software development, to afford mediators and local development teams more control in responding to context-specific requirements; travelling core development team members, coupled with software development-related capacity building, to strengthen local development efforts.

From the set of suggested strategies, we regard the progression from development of customizable software packages to providing application platforms, similar to Apple iOS and Android, as an area that demands increased attention in PD and DSD literature.

REFERENCES


In review
Appendix 6: Paper 6

Chawani M.S. A cross-case analysis of the effects of EMR deployment on Antenatal Care Services in Rural Health Centres in Malawi. *Submitted to Journal of Health Informatics in Africa.*
A cross-case analysis of the effects of EMR deployment on Antenatal Care Services in Rural Health Centres in Malawi

Marlen Stacey Chawani

Abstract
The use of Electronic Medical Records in Developing Countries is considered important for monitoring and facilitating the achievement of health-related Millennium Development Goals. Many studies have analysed the effects of EMRs in supporting care provision in hospitals, mostly with a focus on HIV/AIDS services. However, there are limited studies on EMR use for Maternal health services in small primary care facilities in rural settings. This paper aims to address this gap by presenting findings from evaluation of two EMR systems implemented to support Antenatal care in two rural health centres in Malawi. Whilst previous studies have focused on providing quantitative measures of the effects of EMR systems, this paper presents a qualitative analysis of the effects of EMRs on Antenatal care services in rural settings. This allows an in-depth analysis of the nature of the changes that take place when EMRs are introduced in such settings. The study reveals that EMRs have the effects of redistributing work and increasing collaboration among different types of health workers; increasing attention and knowledge on the health domain, and redistributing risks in care and data quality.

Keywords: Antenatal care, EMR systems, evaluation, effects, rural health centres, developing countries, Malawi, qualitative research.

1. INTRODUCTION
The fifth goal of the Millennium Development Goals is to improve Maternal health with specific targets to reduce Maternal Mortality, and to achieve universal access to reproductive health. Antenatal care is one of the Maternal health services important for preventing Maternal deaths as it provides a platform for delivering several Maternal and new-born interventions. However, Developing Countries in Sub-Saharan Africa are struggling to provide quality Maternal health services including Antenatal care (ANC). Studies reveal there is a substantial quality gap in the provision of ANC with fewer women receiving the full range of interventions during pregnancy (Kinney et al., 2010; Lungu et al., 2011). Furthermore, the quality of Maternal health data itself is considered unreliable which makes it challenging to monitor progress of various interventions (Sharan et al., 2009; Summers, 2009).

Electronic Medical Record (EMR) systems are being implemented as one way of improving the quality of health services through efficient information management (WHO, 2012). EMR systems are expected to primarily improve the quality of data recorded in health records, accessibility of patients’ data by healthcare providers for continuity of care, support clinical decision making, and simplify generation of mandatory reports to the higher authorities (Car et al., 2008; Chetley, 2006; WHO, 2006; WHO, 2012). Within the context of Developing Countries, several studies have reported implementation and use EMRs to support healthcare services. These implementations have mostly been at a small scale focusing on specific health programmes or hospital departments, with the majority of studies reporting EMR use to support HIV/AIDS and TB programmes (Fraser et al., 2005; Oluoch et al., 2012; Castelnuovo et al., 2012; Douglas et al., 2010). These studies have shown that EMR systems are a valuable aid in supporting clinical management of an increasing number of patients and for reporting. Other studies have also reported the use of EMRs to support primary care services including
Maternal and Child health, and outpatient clinical care, for instance, in Kenya (Rotich et al., 2003), Cameroon (Kamadjeu et al., 2005), India (Singh et al., 1997), Malawi (Waters et al., 2010), Tanzania (Ngoma et al., 2012), Zambia (Chi et al., 2011), and Nigeria (Thompson et al., 2010). These studies are considered to attest the feasibility of implementing EMR systems in primary care settings of Developing Countries.

Reviews of EMR literature reveal that most studies within health informatics have focused on objective quantitative evaluations of the impact of the systems on healthcare processes and outcomes on patient care (Car et al., 2008; Greenhalgh et al., 2009; Fitzpatrick & Ellingsen, 2012). In addition, literature reviews of EMR systems in Developing Countries indicate that there are limited rigorous evaluation studies and call for more scientifically rigorous studies that have clearly defined measures, for instance, randomised controlled trials, cost-benefit studies and cost-effectiveness studies (Blaya et al., 2010; Oluoch et al., 2012). However, other researchers have argued that the impact of EMR systems cannot simply be measured by standardised factors such as efficiency and cost because such views neglect to reflect on the ambiguous nature of such technology and the changes in work practices (Berg, 1999; Vikkelsø, 2005; Boulu, 2009). As a result, pre-set measurement instruments often miss unpredictable relevant changes that take place (Berg, 1999). Thus, researchers argue for employing qualitative research methods that allow in-depth analysis of the nature of changes in the healthcare work associated with the introduction of EMRs (Berg, 1999; Boulu, 2009). Therefore, the aim of this paper is to present a qualitative analysis of the effects of implementing EMRs on Antenatal care services in rural primary care settings in Malawi, a Developing country in Africa. The paper contributes to the growing body of evidence on the impact of EMRs in Developing Countries, with a specific focus on addressing the question: what are the effects of implementing EMR systems on Antenatal care services in rural primary care settings of Malawi?

With the specific focus on rural settings, the qualitative approach allows for an in-depth analysis of the social and technical aspects that resulted in the observed use and the perceived effects of the EMR systems. Such an analysis provides deep insights into the changes of Antenatal care work in these settings and thus, highlights important considerations that need to be made when developing EMR systems for such contexts.

The paper is structured as follows. The next section presents a review of literature on EMR systems in Developing Countries, and on EMR systems evaluation approaches. This is followed by details of the research context and the research methodology in section 3. In section 4, the case descriptions of the two EMR systems are provided. Following this, the findings from the evaluation studies for each case are presented in section 5. The findings are analysed and discussed in section 6 in relation to the presented literature. The paper concludes by presenting a summary of the key insights.

2. LITERATURE REVIEW

2.1. EMR Systems in Developing Countries

Different EMR systems have been implemented to support various healthcare services in Developing Countries. Existing literature reports of their use to support HIV/AIDS programmes, Tuberculosis (TB) programmes, Immunisation, Maternal and Child Health, cardiac disease, and general primary care (Fraser et al., 2005; Fraser & Blaya, 2010; Kamadjeu et al., 2005; Rotich et al., 2003; Chi et al., 2011; Singh et al., 1997; Douglas, 2009; Thompson et al., 2010; Waters et al., 2010; Were et al., 2010; Castelnuovo et al., 2012; Ngoma et al., 2012; Anantraman et al., 2002). The range of functionality in the EMR systems included patient registration, visit data collection, tracking/monitoring patients and their
treatments in the health programs, medication order entry, drug/supplies inventory management, appointment scheduling, decision support, statistics and generating reports. Decision support systems have received attention as a possible solution to the lack of trained clinical personnel, especially in rural areas of Developing Countries (Blaya et al., 2010).

There are mainly two modes of implementation that are employed for EMR systems. The first and most common mode is whereby paper-based forms/tools are used by the health providers to record the patient/client’s information during consultations. The form is then used by other staff (e.g. a data clerk) to enter the data into the EMR and this is referred to as retrospective data entry (Douglas et al., 2010; Oluoch et al., 2012). The other approach is whereby the health providers use the EMR directly during consultations with patients. These systems are referred to as Point of Care (POC) or Provider-based EMR systems (Douglas et al., 2010; Chi et al., 2011; Castelnuovo et al., 2012). Researchers have argued that when data entry is retrospective, there is a tendency to transfer the deficiencies of a manual registry to the computerised registry leading to missing and inaccurate data; and that it hinders the realisation of the positive impact that protocol guidance and decision support features can add to patient-level clinical care (Tomasi et al., 2004; Mamlin et al., 2006; Douglas et al., 2010; Castelnuovo et al., 2012). However, others have argued that clinical summaries from EMR systems can still assist in patient care even when providers have almost no direct interaction with the computer (Were et al., 2010).

There are various challenges identified with regards to the implementation and use of EMR systems in Developing Countries. The first challenge is associated with low computer literacy of health workers (Sood et al., 2008; Oluoch et al., 2012). To address this, in some of the cases, health providers undergo computer training prior to deploying the EMR system in order to familiarize them with using computers, e.g. (Rotich et al., 2003; Ngoma et al., 2012). Others, however, have opted for simplifying the interface design and tools, for instance, opting for touchscreen devices instead of the conventional desktop or laptop computers (Douglas, 2009).

Shortage of qualified staff is another problem that challenges the use of EMR systems (Sood et al., 2008). The shortage leads to high workload for the available staff, and this is often the reason why retrospective data entry, done by data clerks, is opted for. Another challenge in Developing Countries is the lack of systems for accurately obtaining unique identification for patients (Rotich et al., 2003; Piette et al., 2012; Douglas, 2009). In addition, low literacy contributes to inconsistent spelling of patients’ names and addresses (ibid.). Implementers have therefore addressed this by implementing patient registration systems that produce patient ID cards e.g. (Rotich et al., 2003; Douglas, 2009).

Other identified challenges to implementing EMR systems are: poor electricity and ICT infrastructures which results in a lack of reliable electricity and internet access; and lack of local technical expertise to support the systems (Sood et al., 2008; Douglas, 2009; Lewis et al., 2012).

2.1.1. Effects of EMR systems

EMRs are expected to improve the quality of care, the efficiency of the care process, and reduce healthcare costs (Chaudhry et al., 2006). Most evaluation studies have focused on process indicators, and attitudes of users or patients, rather than costs and patient outcomes (Blaya et al., 2010). Evaluation studies of EMR systems in Developing Countries have reported several benefits to health services. Improvement in the accuracy and completeness of data is one of the identified benefits (McKay & Douglas, 2008; Castelnuovo et al., 2012). This has been attributed to incorporation of checks/validations in the EMRs at the time of data
entry, as well as having real-time data entry which eliminates transcription errors and allows
immediate verification of the data while the patient/client is still present (*ibid.*). Castelnuovo
et al. (2012) also indicate that EMR systems can make the clinic staff to gain knowledge and
experience, and awareness on data quality, thereby contributing to improvements in the data
quality.

Studies have also reported the effects on efficiency in terms of: time saved in locating patient
information and in producing monthly reports; reduced waiting time for patients, reduced
provider time per patient and shorter visits in general (Rotich et al., 2003; Fraser et al., 2005).
Blaya et al. (2010) reveal that the use of fingerprint scanners and barcode scanners decrease
time for locating records. Automation of some functions such as calculation of pills and
appointment dates and assessment of adherence were also considered to increase efficiency of
healthcare provision (Msukwa, 2011). However, some cases also reported an increase in
workload and duration of consultation time due to introduction of EMRs, e.g. Kamadjeu et al.
(2005).

Another positive effect of EMR systems identified in existing literature is reduced medication
order errors and increased adherence to healthcare protocols (Fraser et al., 2005; Kamadjeu et
al., 2005; Douglas et al., 2010; Oluoch et al., 2012). This is associated with decision support
functions within EMRs such as: computer alerts or reminders to prescribe drugs, administer
vaccines, and to request for lab orders; warnings on drug dosage, drug incompatibilities,
abnormal lab results and other risk factors (*ibid.*).

Furthermore, the ability to track patients to detect risk factors, complications and absentees,
and to monitor and remind patients of healthcare needs or treatment are other EMR functions
considered to have a positive effect in improving the quality of care (Tomasi et al., 2004;
Blaya et al., 2010).

Looking specifically at Maternal health services, there are limited evaluation studies that have
been reported from developing countries. From an implementation in Nigeria, Thompson et al.
(2010) indicate the EMR system was perceived by health workers to have the following
effects: reduced time for gathering information for monthly reporting; producing an accurate
report without human mistakes, allow for more detailed data analysis, encouraged staff to
collect completed forms, and increased client attendance because computers are associated
with an advanced clinic. Singh et al. (1997) indicate that, in India, EMR reports on
immunisation drop-outs were used by health workers to communicate health information to
the community which led to a reduction in the drop-out rates and increased utilisation of
services. Nevertheless, the authors acknowledged that credit for the improvements could not
fully be given to the EMR system.

In general, the existing studies have focused mainly on evaluating pre-specified effects and as
such do not fully examine unplanned effects and consequences of EMRs which may entail
new risks (Kaplan, 2001; Ash et al., 2004; Stoop & Berg, 2003). In addition, there is a
potential bias of reporting ‘successful’ projects with positive effects as unsuccessful cases are
hardly published (Berg et al., 2003; Greenhalgh et al., 2009). Therefore researchers argue for
undertaking qualitative evaluations that are grounded in a sociotechnical perspective, which
allow in-depth investigation of why and how the systems are being used (or not), and the
planned and unplanned effects (Ash et al., 2004; Berg, 1999; Stoop & Berg, 2003; Kaplan,
2001). I present more about sociotechnical evaluation approaches in the next section.
2.2. Sociotechnical Evaluation Approaches

Sociotechnical approaches recognize the interrelation between technology and its social environment, and aims to increase understanding of how information systems are developed, introduced and become part of social practices (Berg et al., 2003). Sociotechnical evaluations involve researching the way technical and social dimensions change and shape each other over time (Cresswell & Sheikh, 2014). The dimensions that may be studied include implementation strategies, attitudes and experiences of individuals, organizational consequences, and impact on quality of care (ibid.). There are various theoretical frameworks used in sociotechnical evaluations, such as: the theory of Diffusion of Innovations; Human, Organization and Technology-fit factors; and Social Shaping of Technology (Cresswell & Sheikh, 2014; Clausen & Yoshinaka, 2004; May et al., 2003; Yusof et al., 2008). In this paper, I adopt theoretical perspectives within Social Shaping of Technology.

From a Social Shaping of Technology perspective, evaluation of EMR systems is focused on how the technology affects the distribution and content of work tasks, information flows, and the visibility of the work (Berg, 2001). Along the same lines, Vikkelso (2005) argues that there are three dimensions of medical practice that are affected by the introduction of EMRs, and these are work tasks, organisational attention, and risks.

With regards to work tasks and responsibilities, Vikkelso (2005) indicates that some work tasks may disappear while others emerge. Some of these new tasks are officially recognised whereas others are left as invisible work. Furthermore, the workload is not equally distributed among staff. In relation to organisational attention, she argues that attention may weaken on some aspects of care and increase the focus on other areas. In terms of risks, Vikkelso (2005) argues that while EMRs are assumed to reduce notorious risks of errors in patient treatment, they may also introduce other risks for patients, for instance, inconsistent medical information across documents. As such, it may not be obvious that the introduction of EMRs has resulted in work procedures becoming better or more efficient all in all. Rather, it results in a different kind of medical practice with a new distribution of work, responsibilities, capabilities, attention and risks (ibid.). Hence, the effects of introducing EMRs should be measured in terms of altered work practices, refocused organisational attention and new kinds of risks.

3. STUDY CONTEXT AND RESEARCH METHODOLOGY

3.1. Antenatal Care Services in Malawi

Antenatal care relates to the healthcare of the pregnant woman and her foetus from conception to the onset of labour (MoH, 2009). In this regard, standardisation and continuity of care throughout the pregnancy is of central concern. Within the Malawi healthcare system, the Focused Antenatal Care (FANC) approach is the operational protocol, which encourages women to have a minimum of four visits (ibid.). The visits are targeted in that they are supposed to take place during specific periods within the pregnancy. The activities conducted during each visit consist of measuring vitals (weight, height and Blood Pressure), providing TTV immunization, conducting lab tests (for HIV, Syphilis, Haemoglobin, and urine protein), taking the woman’s history and current pregnancy details, planning for delivery, conducting the physical examination, scheduling the next visit, prescribing and administering drugs, giving bed nets and registering the visit in an ANC register for the facility. Some of these activities are only conducted on the first visit (e.g. history taking), and therefore there are fewer tasks done on subsequent visits. A detailed description of the activities has been presented elsewhere.

Each woman has a booklet, called a health passport, which is used by health providers to record the client’s information during care provision. The booklet consists of specifically-
designed antenatal care pages for recording the care activities for each pregnancy. At the end of the visit, the information from the health passports is transcribed to the antenatal care registers and the health passport is kept by the woman. During the registration, the client is given a sequential number from the register and the number is copied to the client’s health passport. This number is used to retrieve their record in the register during the subsequent visits. In this way, all the visits for a particular woman (in that pregnancy) are recorded on the same page in the register, with each visit recorded as a row in the register. The data from the registers is compiled on monthly basis in form of a cohort report and is sent to the district level. The aim of the cohort report is to assess the quality of care given to the clients throughout their pregnancies. For example, one of the data elements on the report assesses the number of women who had a total number of 4 visits, which is the recommended number of ANC visits. For the report, the clients are grouped together according to the month they start attending ANC services, thereby forming a cohort.

3.2. Research Setting and Method

This study was undertaken as part of an Action Research project exploring the use of EMRs to support Maternal health in Malawi. As part of this project, two EMR systems, ABC EMR system and XYZ system\(^1\), were deployed in two different rural health centres in Malawi. The description of the system designs is presented in section 4.

3.2.1. Data Collection at Health Centre A

Health Centre A is located in Lilongwe district. It is accessible through a dirt road, and is about 30 kms from Lilongwe city. The staff working in the Maternity section at the health centre consisted of one nurse and two female hospital attendants. The Antenatal care services were provided twice a week at this health centre. New clients attended ANC services on Mondays, and subsequent visits were conducted on Thursdays. Other Maternal health services, such as family planning and postnatal check-ups were provided on the other days of the week.

The ABC EMR system was deployed at Health Centre A in March 2012. Fourteen health workers were trained prior to deployment and these were one nurse, three hospital attendants, one medical assistant, one statistical clerk, eight Health Surveillance Assistants (HSAs), and one assistant environmental health officer. Initially, two touchscreen clinical workstations were installed at the health centre, one in the nurse’s ANC examination room, another at the maternity registration desk. However, after two months of use, another workstation was installed in another room for purposes of history-taking.

An evaluation of the system in use was conducted from September to October 2012. The data was collected through interviewing the users of the system. Semi structured interviews were conducted with the nurse, two hospital attendants, the statistical clerk, and one HSA. Six clients were also interviewed to get a sense of the client’s perspective of the services. Observations of the software in use were done for six days and the observation hours per day ranged from four to five hours. A comparison of the data in the EMR system and the data in the registers was conducted for clients who had started attending ANC in April 2012. A meeting with the health workers was conducted at the health centre in November 2012 to discuss the evaluation findings.

3.2.2. Data Collection at Health Centre B

Health Center B, is located in Dowa district, and is about 50 kms from Lilongwe city. It is located near one of the trading centres in the district and is along a tarmac road that connects several districts to Lilongwe. At the time of deploying the system, the staff working in the

\(^1\) Not the real names.
Maternity section at the health centre consisted of three nurses and three female hospital attendants. Antenatal services were provided throughout the weekdays; however, services for new clients were mainly conducted on Fridays, and subsequent visits were conducted from Monday to Thursday. Other Maternal health services, such as family planning, postnatal check-ups were also provided throughout the week.

The XYZ system was deployed at the health centre in November 2012. Prior to the deployment thirteen health workers were trained on how to use the system. These were a medical assistant, a statistical clerk, three nurses, five hospital attendants, and three HSAs. Two workstations were installed at the health centre, located at two registration points.

Evaluation of the system in use was conducted from July to August 2013. Semi-structured interviews were conducted to collect data from the health workers and clients. Ten health workers were interviewed consisting of three nurses, four hospital attendants, two HSAs and the medical assistant. A total of nine clients were interviewed. Observations of the services were also conducted at the health centre over a period of six days, with the hours per day ranging from four to five hours. An analysis of the data in the EMR system was conducted to review the data captured during the month of July 2013. A review meeting was conducting at the health centre with the interviewed health workers to discuss the evaluation findings.

3.2.3. Data Analysis
The interviews were audio recorded, and therefore, the analysis involved transcribing the interviews. Notes were also taken during the observation of services. The findings were organised into themes based on the interview guide. These themes were on the workflow, use of the system, advantages and disadvantages of the EMR, most/less useful features, reliability of the data, influence on ANC knowledge, challenges/problems faced, and recommended improvements.

Based on the content of the findings and review of existing literature, the findings on the effects have been organised into the following themes: workload, time taken in service delivery, knowledge of ANC work, data storage, data accuracy, data completeness. The discussion of these effects has been guided by the three dimensions of medical practice proposed by Vikkelsø (2005), which are work tasks, organisational attention, and risks.

4. CASE DESCRIPTIONS: THE ANTENATAL CARE EMR SYSTEMS
The aim of the research project was to implement EMR systems that would support health workers in the provision of Antenatal care services. Based on findings from a situation analysis of the services, and discussions with various stakeholders, system requirements for the health centres were developed. The functional requirements for the proposed ANC system were specified as: registering ANC clients; capturing and validating client’s antenatal care data; providing alerts and reminders for patient care based on the patient data entered; reviewing client’s ANC data captured; scheduling ANC appointments; ending ANC service for the pregnancy; producing statistical reports; and reviewing a client’s ANC history for previous pregnancies (i.e. if the previous pregnancy was captured in the system). The specific designs and functionality of the two EMR software applications are described later in this section.

The target health facilities had no electricity; therefore the type of hardware infrastructure was of concern. The research team decided to implement the solutions based on ABC hardware technologies as they had proved to work in rural health centres using renewable sources of energy. This infrastructure consisted of an energy solution based on solar power and low power consumption hardware (similar to what is described in another paper). The technical
design adopted a server-client setup with several workstations at different points of care. Each health centre had a server on site which hosted the EMR application. A Local Area Network was also installed at each health centre. The main component of the workstation was a touchscreen computer. In Health Center A, the workstation also had a thermal printer and a barcode scanner as shown in Figure 1; whilst in Health Center B, the workstation had a keyboard and mouse as shown in Figure 2.

4.1. ABC EMR System
The overall goal of the ANC EMR system was to support the Antenatal care services, by capturing all the details that were recorded in the client’s health passport and the Antenatal register in order to produce required reports including the monthly cohort report. The software development process and overall design principles have been described in another paper. In brief, the design of ABC EMR systems adopts a Point of Care (POC) approach whereby health workers use the workstations to record client’s information during clinical encounters. To increase usability for a POC system, the touchscreen interface has been chosen as a solution that is easy to learn and use considering low computer literacy among health workers. In addition, a wizard-like approach to capturing information is used whereby each screen is dedicated to collecting a single piece of data, as shown in Figures 3 and 4. In this way, large forms are represented as a series of steps/questions. This allows for more transparent branching of data elements such that data elements that do not apply for that client are never shown. Furthermore, the workstation is designed as an appliance model computer in that the device is applied to the sole purpose of running the EMR application rather than a general computer.
At patient care level, the ABC EMR software functionality consisted of: client registration; capturing ANC information, and reviewing the ANC service history. Client registration involved capturing of basic demographic data consisting of the client’s name, age/date of birth, place of residence, mobile number, and occupation. The sex of the client was automatically indicated as female since it was for antenatal care clients only. At the end of the registration process, the system automatically printed out a sticker that had the patient name, birthdate, place of residence, patient identifier number and a barcode representation of the ID number. The sticker could be affixed on the client’s health passport, as shown in figure 5. The barcode is used to search/retrieve a client’s record in the system using the barcode scanner.

Once the client was registered, different types of information could be captured into the system. The system had a patient dashboard which provided links for entering Antenatal care data and for viewing the data that had been captured for that particular client. For entering the data, the dashboard provided links to two kinds of data, patient history data and current visit data. The patient history was collected once, during the first visit. The history data was organized into four categories - obstetric history, medical history, social history and surgical history, with each of these categories having a set of data elements (i.e. questions) that had to be entered. For instance, under obstetric history, the number of pregnancies (Gravida), deliveries, abortions were collected as well as the specific details of each delivery and abortion. All the questions in a selected category had to be answered/entered before the data could be saved in the system. The patient history could be printed on the label stickers and affixed in the health passport (see Figures 6 and 7).
To capture the current visit details, the current visit option on the patient dashboard provided links to several categories of visit data namely: vitals, lab results, ANC physical examination results, current pregnancy details (i.e. data captured once during the pregnancy such as LMP), scheduling the next visit, drug prescription and any other outcomes as shown in figure 8. The captured visit data could be printed on the label sticker and affixed to the health passport, as shown in figure 6 and 9.

Figure 6: Obstetric history sticker (left side) and lab results sticker (right side) placed in a health passport

Figure 7: a detailed obstetric history sticker placed in a health passport
The data entered in the system could be viewed from various tabs on the patient dashboard. The tabs were colour coded to show the status of the data (Figure 10). A yellow colour indicated the data had not been entered, red colour indicated there was a danger sign or high-risk factor within that group of data, and black indicated the data had been entered and there was no high-risk factor.

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2 This is dummy data
To correct the Antenatal care data entered, firstly the wrong data had to be deleted which was done from the patient dashboard. After this, the data could be re-entered. This implied deleting and re-entering all the data in that category, e.g. the obstetric history. However, for the demographic data, it was possible to update the specific data element (e.g. name or address) directly and print a new sticker.

The system also provided statistical information on the services provided in two ways. Firstly, the system dashboard displayed a summary of clients registered and number of clients who had received a particular type of care, such as the number of clients registered and the number of clients whose obstetric history had been entered in a day, as shown in figure 11. Secondly, the system could produce ANC monthly cohort reports for the facility.

![ABC EMR system dashboard](image)

**Figure 11: ABC EMR system dashboard**

### 4.2. XYZ EMR System

XYZ EMR system is a free and open source generic software for collecting, managing and analysing transactional, case-based data records. The XYZ EMR is a module of the XYZ platform, a web-based solution for collecting, managing and analysing aggregated health data. The XYZ EMR system provided functionality for maintaining data about individuals enrolled under longitudinal health programmes, which could be aggregated and fed into the main aggregated data warehouse in the same XYZ System. The XYZ EMR aimed to provide a basic transactional system. The generic XYZ EMR was customised to support Antenatal care service provision according to work practices at the health centre. Details of the customisation process have been described elsewhere.

The customised software that was deployed was XYZ version 9 and had the following patient-level functionality: client registration, enrolment to ANC programme, visit data entry and scheduling of visits, tracking/monitoring services provided to a client. The XYZ also had the possibility to configure aggregation of the patient data for monthly reports; however, the

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3 This is dummy data
required cohort report was not configured in the deployed software due to challenges in the customisation process (which are presented in another paper).

The registration of the client involved capturing the demographic details on a form as shown in figure 12. Some of the details were mandatory to capture such as the name, gender, age/date of birth, residential village. A system unique identifier was generated automatically for the client after registration. However, this unique ID could only be viewed when viewing the client’s profile in another window. The ANC registration number from the registers could be entered as an identifier for the programme, only after enrolment to the ANC programme.

![Client Registration form in XYZ system](image)

Figure 12: Client Registration form in XYZ system

In order to retrieve a person’s record, search functionality was provided for as shown in figure 13. Different criteria could be used to search including the name or identifier. The client record could also be retrieved by looking through a list of all the clients registered at the facility.

![Client search functionality](image)

Figure 13: Client search functionality

Once the client was registered, she could be enrolled into the ANC program. The enrolment required specifying the date of the first ANC visit and the LMP date. The system then automatically calculated the visit dates for all the subsequent visits based on the
recommended gestation periods in the FANC protocol, as shown in figure 14. The visits were displayed as color-coded boxes to show the status of the visit. Green was used to indicate the visit had been completed, purple indicated the visit was incomplete (but had some data), red indicated the visit was overdue, and yellow meant the visit was scheduled in the future. The visit dates could be modified in a separate tab, labelled ‘Modify due/visit dates’ in figure 14.

The client data for the visit could be entered by firstly selecting the visit and then specifying the actual visit date, which was indicated as the report date. Once the report date was specified, the data entry form for the visit was displayed. Once the data had been captured on the form, it could be validated based on validation rules configured during customisation. It was also possible to mark the form as ‘completed’ which indicated that data entry for that visit had been completed.

The XYZ system also had functionality for generating an ANC program summary report for a particular period. This provided a summary of the clients registered during the period and the status of their visits.

5. FINDINGS FROM THE EVALUATIONS

5.1. ABC EMR System Implementation

5.1.1. Antenatal Care process flow
A sequential flow of activities for service delivery had been defined together with the health workers during training & deployment. However, during the evaluation, it was observed that several of the activities occurred concurrently. The activities of weighing, client registration (in the EMR) and TTV immunization often occurred concurrently at the waiting area/registration desk when several health providers were available. In addition, sometimes the nurse also did Blood Pressure examinations in the nurse’s room while these other activities were taking place. Simultaneously, an HIV testing counsellor did the HIV testing.
After the registration, the clients went into the history taking room where the weight and TTV were entered in the EMR and the patient history was taken, and then they went for HIV testing (if it wasn't done already). The client was expected to go to the nurse’s room for physical examination when all these activities had been done. It was indicated that the health workers coordinated among themselves on the work flow. One health worker explained the observed situation as follows:

“First visit, it depends on how many people are there, everyone wants their work to be done quickly on their side, so what happens is some women are taken to be registered in here(history room), some are being tested for HIV, when they are tested there the nurse takes their BP.” [Interview, Sept. 27, 2012]

However, sometimes disorder was evident due to the concurrent activities. For instance, there were cases where some clients went into the nurse’s room for physical examination before getting their HIV results or before going for history-taking.

For subsequent visits, the workflow was more straightforward since it required fewer activities. The work flow was such that the clients would be weighed and TTV checked at the waiting area. The weight and TTV would then be entered in the system and then the client would go into the nurse’s room. If there were clients who had not previously been registered in the system, after taking their weight, the client would go into the history-taking room where they would be registered, their weight and TTV entered into the EMR, and their patient history would be taken.

For every visit, after physical examination and getting drugs in the nurse’s room, the client was expected to go back to the registration desk for registration in the ANC register book and to receive Iron tablets (if prescribed). However, it was noted that not all clients went back to the registration desk after the nurse’s room; instead they left the facility without being registered in the ANC book. Two reasons were indicated for this. Firstly, sometimes the nurse could not find the client to be pregnant hence it was considered an unconfirmed pregnancy, and such cases were not supposed to be entered in the register book. Secondly, it was indicated as a mistake made by the clients i.e. they just left without going to the registration desk. During one visit, it was noted that some clients had left without being registered in the book and one health worker attributed it to the fact that the clients had already received the iron tablets before going for consultation with the nurse, and therefore the clients probably didn’t think there was a reason to go back to the registration desk.

5.1.2. Roles and Scope of System Use

Prior to the system deployment at the facility, the nurse was the primary service provider for ANC, conducting the tasks of: history-taking; taking BP and other physical examinations; prescribing and administering drugs; and scheduling visits. The hospital attendants mainly performed the tasks of registering the clients in the ANC book, dispensing iron tablets and sometimes weighing the clients and taking their BP. The HSAs were the ones who weighed the clients most times and also provided TTV immunisation. The statistical clerk was mainly involved in administering ART drugs to the ANC clients who were found HIV positive (at the ART clinic) and in obtaining monthly statistics from the nurse for reporting.

Due to the deployment of the system, the roles of the health providers changed in several ways. The HSAs, hospital attendants and the statistical clerk were given the responsibility to register the clients into the EMR system. The statistical clerk was also responsible for creating new users in the system and generally functioned as the local support provider. The HSAs, hospital attendants and clerk also shared the responsibility of measuring the weight and height.
of clients and entering these vitals into the system. Although the idea behind the point of care approach was that these details should be captured during the measuring activity, and thus replace writing in the health passports, the providers often recorded the weight and height in the health passport first and captured those details in the system later on. The HSAs, attendants and clerk were also responsible for entering TTV provided to the client on that visit, whilst the nurse was responsible for entering previous TTV received prior to the current pregnancy. Another change was shifting of the history-taking task from the nurse to the other staff (i.e. HSAs, attendants and the clerk).

Nevertheless, there was also ‘overlapping’ or shared use of some functionality in the system depending on the circumstances, for instance, capturing the Blood Pressure (BP). At times, the BP would be taken by the nurse and entered immediately in the system. In other cases, the nurse would record in the health passport or on a piece of paper and it would be entered by the other staff later on. One health worker explained the situation as follows:

“Sometimes the women are called for BP testing whilst we’re doing registration (or other things) so you find that the first clients their BP was not measured so for those, she’ll measure them and enter into the computer immediately. But if we see that their BP has been measured, we enter it in here [patient history room] so she doesn't have to, she just enters the lab results and does the physical examination.”  [Interview, Sept. 27, 2012]

In addition to the other activities described above, the Hospital attendants also registered the clients in the ANC book and dispensed Iron tablets to the clients.

**5.1.3. Effects on ANC work**

**5.1.3.1. Nurse’s Workload**

Due to the changes in the distribution of ANC work among the health workers, a perceived advantage of introducing the system was reduced workload of ANC work on the nurse. One health worker explained as follows:

*The system has helped because before that it was just pressure for one person [the nurse] but this has provided the opportunity for many people to know how ANC is done, it’s really helped. That the woman should come with the husband, and when they come, they’ll start with this and then that, like that.*  [Interview, Sept., 2012]

Other health workers also expressed a similar point as follows:

*“It has improved because at first work was tough. It was tough for the nurse to start writing everything so the workload was a lot. Now the workload is less. With the system everyone is interested to take part so we are simplifying work.”*  [Interview, Sept., 2012]

*“The work is improving because like the nurse, in the past, she would start working in the morning but finish very late in the day, because everything was for her, but now the work load for her is less, because some parts like history we help her so she does a smaller part there. While at first everything was hers…[ ] In the past we were only helping her with weight, height and TTV that’s all. But now its more things we are helping her with so that the work should be lesser for her.”*  [Interview, Oct., 2012]

Thus, it was a common perception among the health workers that the workload for the nurse was reduced due to the fact that more health workers were involved in ANC work.
5.1.3.2. Time taken in service delivery

The health workers perceived the delivery of ANC services to be faster with the EMR system in place. This was attributed to several factors. The first reason was indicated in relation to the fact that there were more health workers doing the work, as previously mentioned. For instance, one health worker explained it as follows:

“With the system things are faster, especially since we have three computers now so one is doing registration, one is doing history like am doing so the nurse’s work is less.” [Interview, Oct., 2012]

The health workers also perceived that capturing information in the system was faster and easier than writing as shown in the quotes below:

“It’s like a shortcut cause at first you had to write everything but now you just ask questions and enter in here” [Interview, Sept., 2012]

“ANC work is improving with this system because everything is shortened. Writing was difficult and was making the head boil...Of course, we started writing since Standard 1 up to now, but still, at our age, writing [laughs], for me, this is good, it makes it shorter.” [Interview, Oct., 2012]

“With the printing, there is no need for us to be writing anymore, most of the things were already installed, like the obstetric [history], there are so many things there so for a person to be writing, to be asking and writing, asking and writing, whilst in here [the system] its already installed so its not difficult, just take it [printout] and stick in there [health passport]. So things like that reduced the work” [Interview, Oct., 2012]

Some clients also perceived service delivery to be faster. One client explained that previously they were writing so it was slow. However, other clients were of the opinion that service delivery was slower because there were many questions being asked as shown in the quote below:

“Now it’s slow because there are many things being done... like the questions, so when they’re asking they are pressing the computer, so that also takes time... Before there weren’t many questions like now” [Client Interview, Nov., 2012]

A comparison of the consultation times before and after deploying the EMR system revealed mixed results with regards to whether service delivery was faster or slower. This was due to the fact that consultation time was dependent on the specifics of the client, for instance, the higher the number of previous pregnancies the client had, the more time it took to collect the obstetric history.

5.1.3.3. Knowledge of ANC work

The involvement of other cadres in ANC work was perceived to have led to increased knowledge on ANC work activities. This is reflected in the first quote presented in section 5.1.3.1. Another health worker expressed the effect on his knowledge as follows:

“It has helped me because I am a data clerk so I have to know what is happening everywhere, so with the introduction of the computer, it has made me to advance in terms of my understanding of terms for ANC.” [Interview, Sept., 2012]

Another health worker also indicated that he was able to use this knowledge during community activities as explained below:
“It has increased, because we couldn't ask the nurse many things because of time at first, but now we can do it so it’s added new things that we didn't know before. Even when we go out, what we see here, when someone asks us, we are able to answer them clearly cause we are used, it's what we are doing.” [Interview, Oct., 2012]

The hospital attendants had been more involved in ANC work prior to system deployment, as compared to the HSAs and clerk. Nevertheless, they also indicated that their understanding of some terms had improved, for instance, the difference between gestation and fundal height.

5.1.3.4. Data Storage
The health workers perceived that the system improved the storage of client’s information at the health centre since the clients kept the health passports after service delivery. It was indicated that this was an advantage because sometimes the clients lost their health passports. This can be seen in the quotes below:

“Another thing is that all the information is being entered in the system, while in the past, if a woman loses the [health passport] book, we couldn’t follow up properly” [Interview, Sept. 20, 2012]

“When the woman is registered, we don’t have to ask the details again, everything is there, even if they bring a new book, maybe the old book is filled up, we can find them again and simply transfer that obstetric history from the old book to the new book, so information is kept, and that’s very important and useful. Because they can change their name but their information can’t be changed, cause they can remarry [and change the name] but that information is unchanged” [Interview, Sept., 2012]

The second quote also shows that the system was perceived to make it easier to transfer the client’s information if the client obtained a new health passport. This was possible because of the printouts from the system.

5.1.3.5. Data Accuracy
The health workers had different views with regards to the accuracy and reliability of the data in the system. Some of the health workers indicated that, sometimes, there were inaccuracies in the data captured. For instance, clients were indicated as having had a caesarean section or vacuum extraction when it was just an episiotomy. One health worker explained as follows:

“For new visits, the main problem that is there when entering obstetric history, sometimes it is entered as the client had an operation when it was not an operation, it is indicated vacuum [extraction] when it is not vacuum, symphysiotomy, there are still problems.” [Interview, Sept., 2012]

Some of the health workers indicated they had challenges in understanding some of medical terms on the obstetric history. One health worker said:

“When entering, there is symphysiotomy I don't really understand it still, I try to ask but the answers that I get don't really satisfy me. There’s PPH, Eclampsia. I ask them but without the real knowledge, like since I heard like this, let me ask like this. But if the client would tell me those signs are happening, I wouldn't know where to go.” [Interview, Oct., 2012]

It was also noted that some of the health workers did not understand the terms related to abortion cases particularly, Manual Vacuum Aspiration (MVA) and Evacuation and some terms related to the medical history (i.e. Renal disease and Fistula repair).
In addition, it was indicated that, at times, there were inaccuracies when registering clients whereby a client could be registered twice. This was because some of the health workers did not know how to correct mistakes made e.g. to change a client’s name, so they would just register the client again.

It was also indicated that the calculations for some of the drug prescriptions were incorrect. Furthermore, it was discovered that errors were made when entering TTV doses at the registration desk in that instead of only entering the TTV dosage given on that visit, some health workers were including the previous TTV doses. This was because the health workers were not aware that the nurse entered the previous TTV doses as a different data element. It was also noted that at times, incorrect visit dates for the next appointment were entered. For instance, a previous date or the present date was sometimes entered as the next visit date.

However, other health workers were of the view that the data in the system was accurate and therefore reliable. It was indicated that they had tried to sort out some of the previous problems. They further indicated that they try to correct mistakes made:

“It's reliable because we are interested; when we make a mistake we call each other. Even at the end of the day we ask how many have we entered today so if it balances then we are happy, if it’s different, we are dejected.” [Interview, Oct., 2012]

A comparative analysis of the client data in the ANC register and in the EMR also revealed errors in capturing visit numbers. For instance, for one client, the visit number in the EMR was entered as 6 whilst the register showed the client only had 1 visit. In another case, two visits with the same visit number were also found, which made the total number of visits for the client (in the report) to be less than the actual visits a client made. It was also noted that some health workers were uncertain whether to include visits attended in other facilities. For instance, there was one client who had been referred to the referral hospital for scanning services and her referral visit had been recorded in the health passport as an ANC visit. The health worker was therefore unsure whether to include that referral visit when entering the visit number for the current visit.

Furthermore, miscalculations of some data elements of the cohort report were also identified which in turn affected the accuracy of the cohort report. This required correcting the formulas for the calculation of those data elements.

5.1.3.6. Data Completeness

The comparison of the data in the register and EMR also gave an indication on the completeness of the data with regards to missing data. It was discovered that some clients had fewer number of visits recorded in the ANC register when compared to the EMR i.e. some visits were not recorded in the register. This was explained to be due to clients not going back to the registration desk.

It was also discovered that there were some clients who were registered in the system but were not registered at all in the register book. The health workers explained that this was because some of the clients had unconfirmed pregnancies and were therefore not supposed to be registered in the book. On the other hand, the clients were registered in the EMR because registration was done prior to physical examination by the nurse.

In addition, it was discovered that there were missing values in the EMR and on clients’ printouts (stuck in the health passports) for some of data elements such as the weight, Lab tests results, TTV doses, next visit date, and drugs.
5.1.4. Challenges in using the EMR system

There were several challenges faced in using the system, some of these have already been presented in describing the effects on ANC work. Here I present additional challenges that were identified.

5.1.4.1. Capturing Obstetric History

It was generally challenging for the health workers to collect the obstetric history and this was due to multiple factors. First, as previously presented, some of the health workers had challenges in understanding the medical terms. This was due to the fact that they had not received any medical training in Maternal health care.

In addition, it was challenging to collect the history due to contextual factors coupled with the system design, i.e. the logic/sequencing of the data elements. More specifically, the logic and sequence was such that the first data element was the Gravida, which is the total number of pregnancies ever had, including the current pregnancy. The next data element was on whether the client previously had a multiple pregnancy (i.e. twins, triplets etc.), which had options for either a ‘yes’ or ‘no’ answer. After this, the number of deliveries was specified. Based on the number specified, details of each delivery were collected (i.e. the year, place of delivery, gestation age, labour duration, delivery method, condition at birth, estimated birth weight, whether the child was still alive, and if not, the age at death). After this, the number of abortions was indicated and the details for each abortion case were also collected. A validation rule was included to ensure that the number of deliveries plus the abortions should be equal to the total number of pregnancies (Gravida). This was only applicable for cases where a woman never had a multiple pregnancy. Otherwise for multiple pregnancy cases, each baby was supposed to be captured as a separate delivery, thus the number of deliveries could be equal to or even more than the Gravida.

It was challenging to capture the Gravida because when the health workers asked in the local language saying “Uchembere wachingati?”, women often indicated the number of deliveries they had and excluded abortions or miscarriages (still births) because locally/culturally uchembere is often associated with childbirth and children born. As a result, it was only discovered later on when asking the abortions that the Gravida was not inclusive of abortions. This then required recapturing all the previous information in order for the Gravida, deliveries and abortions to balance up according to the validation rule.

In addition, a validation was included which indicated that abortions have gestation of 6 months or less. Thus if the woman lost the baby at 7 months, it was supposed to be entered as a delivery and not an abortion. The local term for abortion is ‘kutaya mimba’ but locally/culturally this is often associated with induced abortions which are illegal. Therefore, to ask about the abortions, the health workers used the term “kupita pambali” which locally/culturally is used to refer to miscarriages including still births or neonatal deaths. Thus, the health worker would start capturing the abortion details only to discover that the pregnancy was 7 months or more and therefore it had to be captured as a delivery with a still birth or neonatal death. This therefore required going back and recapturing all the information.

Furthermore, it was indicated that the health workers faced challenges in capturing cases where the client previously had twins as they were not sure whether to enter it as one delivery or two. One health worker indicated that sometimes they didn’t capture the other baby’s details.
5.1.4.2. Correcting captured data

As previously explained, some health workers had challenges in correcting captured data on obstetric history as well as registration of clients. One health worker indicated as follows:

“Right now, maybe when you make a mistake, to find it for example to delete something, I don’t know how to do it”. [Interview, Oct., 2012]

Another aspect that made it challenging was that it was not possible to correct one specific item, rather it required deleting all the relevant/associated data elements within that grouping and re-enter them all. For instance, it was noted that during nurse’s consultation with clients, some of the clients would indicate a complaint towards the end of the consultation, after the nurse had already captured the examination findings. This implied having to delete and re-enter all the examination findings (i.e. fundal height, position, presentation etc.) just in order to capture the complaint. As a result, some of the health workers simply corrected the information on the printout and not in the EMR leading to inconsistencies.

Another aspect that made it challenging to correct the data was that the privileges were set in a way that only the one who had entered the data could delete it. One health worker presented the following example of when they wanted to change the data but could not:

“Through my experience, when you register someone and then you go to the social history, let’s say you indicated that the person smokes, but on the next visit you realise this was a mistake, how can you change it because it seems the star for deleting does not appear.” [Interview, Sept., 2012]

Thus, even if a mistake was recognised, if the health worker who entered it wasn’t there, or if they didn’t know who entered that data, it could not be corrected.

5.2. XYZ system Implementation

5.2.1. Antenatal Care process flow

During the evaluation, it was indicated that the workflow was such that the clients were registered at the end of the visit rather than registering the clients first before going into the nurse’s room (which was the initial arrangement during deployment). Thus both registration and capturing visit details were done at the same time. In this regard, there was minimal change to the workflow prior to deployment since the system was simply used at the end of the visit. It was explained that this was opted for because they were having problems with the initial arrangement in that clients would leave the facility before their visit details were entered as they would say that they had already been registered in the system. As a result, the health workers decided to be doing both, registration and entering visit details, at the end of the visit.

5.2.2. Roles and Scope of System Use

The registration of clients and capturing of visit details in the EMR system was done by the Hospital Attendants and HSAs. It was indicated that most of the times, there were two people available, and therefore one would enter the data in the register while the other entered in the system.

The nurses rarely used the system and they indicated this was due to high workload as they were also required to provide other services i.e. postnatal check-ups, family planning and maternity deliveries. In addition, there had been a change in that a new drug, Misoprostal, had been introduced, which required the nurses to fill another form when administering the
drugs to clients. The nurses were also required to administer/dispense all the other drugs (SP, Iron tablets) themselves. This was previously being done by the hospital attendants.

It was indicated that two of the staff who had been trained, one hospital attendant and one statistical clerk, were no longer working at the facility. Furthermore, others who had been trained from the OPD section did not use the system. One health worker was of the view that some of the trained staff did not use the system due to lack of a table as explained below:

“Because some people since they learnt, they fail up to now, why? Because they’re not serious, they just leave that those ones are the ones trying hard, let them do it. Whilst if there was a timetable people would say, today is my day. We said X should make a timetable so she just said she’ll do it. Because sometimes this thing is ok, but we have a syndrome that there were many of us trained, so why should we only be the ones doing it. So you leave it for your friends and do other things. So for us who use timetables, we see that it would be very good that our timetable we should also incorporate this” [Interview, July 2013]

There were also two hospital attendants at the maternity section who had not been trained on using the EMR. This was because one of them was working at the OPD and had not been incorporated when the training was done, whilst the other attendant was new at the health facility. It was indicated that when these two were on duty, it was the HSA who entered the data in the EMR system or sometimes one of the other Hospital attendants (who were not on duty) would come to enter the data.

5.2.3. Effects on ANC work

5.2.3.1. Time taken in service delivery

The health workers indicated that there was a delay in ANC service delivery with the use of the system which resulted in the ANC clients going home late. The delay was considered to be due to several reasons. Some health workers perceived the delay to be due to the fact that they had not mastered using the system and so they were slow. One of the reasons indicated for this was lack of practicing using the system during their free time, i.e. when clients were not around. The other reason was that the system had not been functioning for almost 2 months because there was a problem with the power system.

Other health workers perceived the delay was because other health workers who had been trained did not help with entering the data in the system, and hence the work was just left to a few people. Another reason given for the delay was that at times, there was only one functioning workstation because the mouse and keyboard for the other workstation had problems and had been taken for fixing. Prior to that, one of the touchscreens was displaying very small text that was not readable and therefore it couldn’t be used. One health worker explained as follows:

“It’s not the same, things have changed but somewhere, maybe because we haven’t mastered it yet, or sometimes its just one person doing it others aren’t there, then for the women to go home, they go very late, delaying is there. So maybe if we all put our heart to it and things are going well, maybe the delaying will be reduced. Because they are entering on one system the other one isn’t working so things can’t go well…. If both were working things can go well but the problem is that those who were trained it’s not everyone who puts in effort” [Interview, July 2013]
Another health worker perceived the delay to be due to services starting late in the day. The delay in service delivery was also expressed by the ANC clients. One client explained as follows:

“In my opinion, the system makes it slow because last month when we came, we left in the evening, it was even getting dark” [Interview, July 2013]

Some of the health workers also perceived the EMR to have increased the workload at the facility, thereby making it time consuming. One health worker explained as follows:

“We see that there is more work because they have to be entered in the register and then in the system after that so it’s like it takes time. But maybe if we stopped using the registers and just used the system it may be a bit faster” [Interview, July 2013]

The delays were also observed to be due to the fact that on subsequent visits, the health workers were also entering data for the previous visits, particularly for clients who had started ANC when the system was down.

Despite the indicated delays, some health workers were of the view that entering in the system was faster than writing in the registers.

5.2.3.2. Knowledge of ANC work
The hospital attendants and HSAs indicated that they had learnt some things about ANC from using the system. One health worker explained as follows:

“For example, when we were not writing in the register, we didn’t know what happens, but when we learnt on the computer and then when we see in the register we know that it’s the same thing we were doing on the computer. For example when a woman comes at 5 months, knowing that the baby has this particular position or how things are, we learnt it there.” [Interview, July 2013]

The HSAs also indicated they knew more information about Antenatal care which was used to give advice to the women in the field, for instance, when facilitating safe motherhood groups in the community.

“For all the trimesters we know how the child is supposed to be based on how the nurses write like heart beat etc., that the woman is supposed to have 4 visits, the 5th one is optional, all of this we knew here, and what they are supposed to get when they come.” [Interview, July 2013]

However, another hospital attendant explained that the knowledge was somehow the same but what was different was that they made sure they collected some information that they were not asking before, such as religion and education. This information was being collected because it was being entered in the system.

5.2.3.3. Data storage
The health workers perceived that the EMR had improved the storage of data because with the registers, the pages go torn, but with the system, the data would always be there as long as it was not deleted. One health worker gave the following example

“the registers get torn, for example the register that we’ve just stopped using, some pages fell out and we can’t find them, which means that we lost that information. While if it’s in the system, everything will be intact” [Interview, July 2013]
Another health worker perceived the EMR to improve storage in that it was not bulky to keep data, it could store data for many clients while for the same amount of clients, there would be ‘heaps of registers’. Some health workers also indicated that the data could be easily retrieved from the EMR if someone was looking for the information.

5.2.3.4. Data accuracy
The hospital attendants and HSAs were of the view that the data in the system was accurate because of the checks and validations in the system. One of them explained it as follows

“Because those in the registers, sometimes when you mess up the numbers, you didn’t know that you’ve messed up the numbers, you would just continue but in the system, when you mess up, the system tells you that you have made a mistake so you go back immediately. Whilst when you are writing with a pencil you just continue.” [Interview, July 2013]

Another health worker explained that the data was reliable because data entry was “on the spot, the owner is right there so you don’t have to think what if I write this. If there is an error somewhere, you are able to go back to the nurse and find out.” [Interview, July 2013]

One of the nurses also perceived that the data in the EMR was accurate because she perceived that the health workers were more serious when entering in the EMR rather than in the register book.

However, it was discovered that some errors were made in recording some data elements such as the HIV status. For instance, the health workers were capturing the HIV test results on subsequent visits as ‘previous negative’ instead of indicating that it was ‘not done’ on that visit. Errors were also made in capturing number of abortions because the nurses wrote it as a code that the other health workers did not understand, e.g. G2+1 meant Gravida 2, 1 abortion.

5.2.3.5. Data completeness
Some of the health workers perceived the data in the EMR to be incomplete because of the gap in using the system when the system was down. Furthermore, the nurses also perceived the data in the registers to be incomplete because they noted that when women came to deliver at their facility, their health passports indicated they’ve had 4 visits or more, but in the registers, they would only find that two visits were recorded.

However, other health workers were of the view that an advantage of the system was that it provided alerts when there were missing data elements and therefore, all the required information was collected as shown in the quote below.

“it helps us because every information related to the woman, when we are entering, if we miss somewhere that is important, the system shows us that you’ve missed this, you’re not supposed to omit this… so every important information from the client is collected unlike in the paper.” [Interview, July 2013]

5.2.4. Challenges in using the EMR system
There were several challenges in using the XYZ system that were identified. Some of the challenges have been presented in the previous sections. One of the challenges faced was that the system had been down for almost 2 months due to problems with the power system. This resulted in a backlog of data that needed to be entered for that period.

Another challenge in using the EMR was on searching for clients in the system. It was observed that some of the users often forgot to indicate or change the search criteria i.e.
whether they were searching by the name or ANC registration number. As a result, when searching, the client could not be found because it was searching on the wrong information. Another challenge with the search functionality was that sometimes the spelling of the names entered in the EMR was different from what was recorded on the health passport, for instance Idess vs Idesi. Thus, the client would not be found if the name spellings did not match. These challenges resulted in duplicate accounts being created for the same client.

In addition, it was noted that some of the users were not familiar with how to change the client attributes that were captured during registration. For instance, the users would discover that they captured the age of the client to be under 9 years old and as a result the client could not be enrolled into the ANC programme. Therefore instead of changing the age of the client, they would register the client as a new client, resulting in duplicate records as well.

Some of the health workers also faced challenges in connecting the devices (i.e. touchscreen, keyboard, mouse, network cable and power adapter). Some health workers indicated that sometimes, when certain health workers were not available, they often struggled to connect the devices or could not identify the source of a problem and therefore at times, they would end up not using the computer that day. This was attributed to low education levels among some of the health workers. One of them explained as follows:

“the problem is that sometimes we are not able to know the problem properly, maybe the cable of the network has moved, we don’t know that it has moved. Maybe this thing, you press with the buttons[ keyboard], when you put it, sometimes it doesn’t show the light, so we just say it’s not working without really knowing what the problem is, because its like English -we don't know it very well. Because at first we didn't know what things mean, so now we are learning little by little.” [Interview, July 2013]

Another challenge in using the system was navigating the computer. For instance, at times, the user would accidentally right-click the mouse and selected some option which led to a new window or tab being opened. The users were then unsure of what happened and how to proceed to get back to the system. One health worker explained as follows.

“when we are entering the data in the system, sometimes you just find that we have opened another page, because we don’t know it very well, so to go back to the right place properly it takes us time because we haven’t mastered it properly. So sometimes we might say the computer has broken down when it’s not, but it’s just because we don’t know where we should press. So that might lead to not using the computer that day and we just write the clients details on a paper.” [Interview, July 2013]

Another challenge indicated was the confusion between the password for logging on to the computer, and that for logging in to the XYZ system. The health workers indicated they had forgotten how to deal with the computer log on screen and if it appeared, they ended up not using the computer that day.

6. ANALYSIS AND DISCUSSION

The previous section presented the actual use of the EMR systems in the two rural health centres, the perceived effects of the systems on Antenatal care work, and challenges encountered in using the systems. There are several differences that exist between these two use cases that should be noted. The software used was different in terms of the interface design whereby the ABC system had each screen dedicated to capturing one data element, while the XYZ had forms with multiple data elements. The data entry was through the touchscreen for the ABC system, whilst the XYZ system implementation had a mouse and
keyboard. The ABC system allowed for printing of the entered data on label stickers while the XYZ system implementation did not provide for printing. In addition, in Health Center A, a point of care approach was adopted for system use, similar to the cases of Douglas et al. (2010) and Castelnuovo et al. (2012); while in Health Center B, it was more of retrospective data entry, which is more common (Oluoch et al., 2012).

Furthermore, the organisation of the services was different in that specific days were assigned for ANC at Health Center A, while in Health Center B, ANC was provided throughout the week together with other services. The staffing levels were also different, for instance, two hospital attendants were usually on duty during the day shifts in Health Center B, while in Health Center A, only one was available per week for both day and night shifts. Health Center B also had three nurses available who took weekly shifts while in Health Center A, only one nurse was available at the health centre and therefore she was never off-duty. Considering these differences, it is challenging to discuss which EMR system is better solely based on the perceived effects, as these effects are the result of the combination or interrelation of the social and technical aspects within that setting.

However, this is not to imply that there are no similarities in the effects between the two cases. For instance, introducing the EMRs was perceived to have increased the knowledge of other cadres of health workers (i.e. HSAs, hospital attendants, clerks) on Antenatal care work in both implementation cases. Furthermore, some of the perceived effects relate to issues that have been identified in previous literature as the areas which EMRs can have a positive effect (Rotich et al., 2003; Fraser et al., 2005; McKay & Douglas, 2008; Blaya et al., 2010; Castelnuovo et al., 2012). In particular, these are issues of efficiency of the care process (i.e. time taken); the data quality in terms of accuracy and completeness; and the management of data i.e. data storage. The health workers perceived the EMR systems to improve data storage in both implementation cases. However, there were mixed views on whether the systems had a positive or negative effect on efficiency and data quality. In the ABC EMR system implementation, the health workers perceived service delivery to be faster with the system in place and some clients had the same view. However other clients were of the view that things were slower with the system in place. Whilst, in the XYZ implementation, health workers and clients perceived that there was a delay in ANC service delivery with the use of the system. In terms of the data quality, there were different views on whether the electronic data was accurate and complete. In the ABC implementation, a general view among the health workers was that the client data captured was accurate and complete, even though they acknowledged existence of some errors in some cases, such as the obstetric history, visit numbers, double registration of clients, and drug miscalculations; as well as some missing data. In the XYZ case, some of the health workers perceived the captured data to be accurate but incomplete because data had not been entered when the system was down for almost two months.

It is, therefore, important to examine the underlying reasons for the perceived effects which provide more insight to the types of changes that occur when EMR systems are introduced or are in use. Therefore, below, I discuss the changes in Antenatal care services from the two EMR system implementations along the dimensions of work, attention and risks, as proposed by Vikkelsø (2005).

6.1. Work redistribution

According to Vikkelsø (2005), introducing EMR systems can lead to redistribution of work with some work tasks disappearing while others may emerge. As already indicated in the findings, in the ABC EMR case, the introduction of the EMR system in Health Centre A led to radical changes in the distribution of Antenatal care work among different types of health
workers at the facility. Before the EMR, the nurse performed most of the tasks but following the introduction of the EMR, the HSAs, hospital attendants, statistical clerk were assigned the tasks of history-taking. In this way, the health workers perceived that the workload was reduced for the nurse, but on the other hand, the workload was also increased for the other health workers. In addition, new tasks were introduced as a result of the system such as the registration of clients into the system, which was given to the HSAs, hospital attendants and the clerk. The clerk also assumed a new role as a super user responsible for creating new users into the system and generally functioned as the local support provider.

In the case of the XYZ system, the tasks of registering clients and entering their visit data were added to the ANC process. The responsibility for these tasks was shared among the nurses, hospital attendants and HSAs; however, the evaluation revealed that it was only the attendants and HSAs who performed these tasks. Thus it could be said that the workload was mainly increased for the attendants and HSAs but not the nurses.

In this regard, the introduction of EMRs, in both cases, came with additional tasks such as the client registration. However, the ABC EMR was designed to replace writing in the health passports and had a printout produced instead. In this regard, data entry was not to be an additional task that increased the workload, but rather it was to replace writing, hence the overall workload (in terms of data capturing) was expected to be the same. On the other hand, the XYZ system implementation was not aimed to replace writing but rather data entry was an additional task to writing in the health passports, therefore it can be considered to have increased the overall workload (on data capturing).

Nevertheless, an emergent consequence of introducing the EMR systems in both cases was that collaboration between different types of health workers increased at the health centres, for instance, the HSAs became more involved in ANC service delivery. Hence the nature of Antenatal care work became more collaborative with the activities occurring more concurrently rather than in a linear workflow. Intrinsically, this also meant a need for more coordination between the health workers in performing the ANC work.

### 6.2. Organisational attention

The introduction of EMRs can weaken or strengthen the attention on certain aspects of care (Vikkelso, 2005). In the ABC case, introducing the EMRs increased the attention of some of the health workers in ANC since most health workers had never used computers before and this was considered a chance to learn how to use one. For instance, some health workers indicated that other health workers mainly assisted in the EMR-related tasks but not recording in the register book. Similarly in the XYZ case, some health workers indicated that they used the system because they really wanted to master the computer.

In the ABC case, the attention was also increased on specific ANC tasks, such as the history-taking, which was new to the other health workers and was often viewed as challenging to capture, as compared to the other details (e.g., weight, height). In addition, the increased attention on the history was noted by the clients who indicated that more questions were being asked as compared to previous pregnancies.

Another area that had increased attention, in both cases, was the LMP date. Prior to the EMR systems, the LMP could be left blank. However, following the EMR implementations, the health workers made more effort to obtain an LMP date as it was a mandatory data element in both EMR applications. Other areas where attention was also increased was the collection of demographic details such as the place of residence, education, occupation, marital status. The attention was also increased on the accuracy of some data elements due to validation rules that
were incorporated in the EMR systems. As a result, the health workers were perceived to be more serious with data collection on the EMR than when entering in the registers as they would seek clarification on the data. This is similar to the observation by Castelnuovo et al. (2012) that EMRs can improve knowledge and awareness on data quality. However, this could also have reduced the attention on other data elements that did not have validation rules or that were not indicated as mandatory.

Furthermore, as already indicated, introducing the EMRs was perceived to have increased the knowledge of other cadres of health workers on Antenatal care work in general. The gained knowledge was not only used during ANC service provision at the facility but also in other areas of their work, for instance, in community level activities. Thus EMRs do not only change the level of attention on certain aspects, it can also improve the level of knowledge on the health domain. This is particularly true for rural primary care settings with limited qualified staff as deployment of the EMR requires the involvement of other cadres of health workers in addition to the main service providers (i.e. nurse/midwives in this case).

6.3. Redistribution of Risks
EMRs are expected to reduce risks in healthcare work such as medication errors and data entry errors (Tomasi et al., 2004; Fraser & Blaya, 2010; Castelnuovo et al., 2012; Oluoch et al., 2012). However, Vikkelso (2005) indicates that EMRs may also introduce other risks. As previously indicated, in both implementation cases, the EMRs were perceived by some health workers to reduce the risk of making errors during data entry due to the validation rules. This has also been indicated in previous studies (McKay & Douglas, 2008; Castelnuovo et al., 2012). The EMRs were also perceived to reduce the risk of losing data due to lost health passports or torn register pages. Furthermore, in the XYZ EMR case, the risk of missing data for some data elements was also perceived to be reduced due to completeness checks on mandatory data elements. However, there were still risks of gaps and errors in some of the data elements that were not indicated as mandatory or those that did not have validation rules in the XYZ system. Similarly, the ABC EMR did not have completeness checks and therefore there were still risks of missing data for some data elements e.g. test results.

In the ABC case, shifting the history-task to other cadres introduced the risk of errors in the history captured, for instance, misdiagnosing cases as symphysiotomy or vacuum extraction cases; which was due to a lack of in-depth understanding of the medical conditions by the health workers. This, in turn, resulted in clients having false-positives on some of high-risk factors. On the other hand, this also introduced the risk of clients with actual risk factors not being identified during ANC. Introducing more details (e.g. symptoms) to be asked for some of the conditions is one possible way to assist the health workers in the diagnosing process. Other areas that also had errors were: in the prescription of drugs where it was noted that there were miscalculation on some drugs; and miscalculation of some data elements on the reporting form.

Another risk that was introduced in both cases was the risk of inconsistent data between EMR data and the paper records. In the ABC case, inconsistency between the EMR data and data in the health passports and registers occurred due to several reasons including challenges in correcting the data which led to data corrections being made on printouts only and not in the EMR or vice versa; and printing visit summaries before all the data was entered. In the XYZ case, a prolonged system down-time led to differences in the EMR data and data in the register book. Furthermore, in both cases, having all clients registered in the EMRs at the beginning of the ANC process led to registration of clients who, for instance, had
unconfirmed pregnancies or were visiting clients, whilst in the registers such clients were excluded.

In both cases, another risk that emerged was the double registration of clients in the EMRs. However, the risk of such errors seemed higher in the XYZ case due to the challenges health workers faced in searching for existing clients in the EMR as well as in challenges in editing or correcting the existing data. In the ABC case, availability of the unique IDs from the system and the barcode scanner reduced the difficulty in searching of clients.

7. CONCLUSION
The aim of this paper was to investigate the effects of EMRs on Antenatal care services in rural primary care facilities in Malawi. The paper therefore contributes to the body of knowledge on effects of implementing EMR systems in rural primary care settings of Developing countries. I have presented a qualitative cross-case analysis of the effects of two Antenatal Care EMR systems implemented in two rural health centres in Malawi.

The findings show that some of the perceived effects relate to issues of efficiency, data quality and data storage which have been identified in previous studies from Developing countries. However, it is challenging to conclude in general whether the services were more efficient, or if the data quality improved due to the redistribution of attention and risks that occurred. For instance, while the attention and accuracy may have improved on some data elements, there were errors that occurred on other data elements. Hence, the analysis shows how the deployment of EMRs introduces different types of risks in healthcare work and in data quality, rather than completely eliminating errors.

The analysis also shows that the EMRs changed the work distribution among the health workers with some tasks being shifted to other cadres and new tasks being created as well. An unforeseen consequence was therefore increased collaboration among different types of health workers, as other cadres became more involved in the ANC work. This may be the case particularly in rural primary settings as the staffing levels of qualified health workers are low. Therefore, the Antenatal care work became more collaborative in nature simultaneously requiring the need for more coordination among the health workers.

The analysis also reveals that introducing the EMRs led to increased knowledge among other cadres of health workers, on the Antenatal care work, due to the increased collaboration. Thus, the organisational attention on ANC work increased at the health facilities.

REFERENCES


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Appendix 7: Research Permits

Marlene Galimoto
University of Oslo

RE: Protocol #662: Implementation and use of information and communication technologies (ICT) to improve maternal health services

Thank you for the above titled proposal that you submitted to the National Health Sciences Research Committee (NHSRC) for review. Please be advised that the NHSRC has reviewed and approved the above titled study.

- **APPROVAL NUMBER**: NHSRC/662
  The above details should be used on all correspondence, consent forms and documents as appropriate.

- **APPROVAL DATE**: 12th March 2010

- **EXPIRATION DATE**: This approval expires on 11th March 2011
  After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the NHSRC secretariat should be submitted one month before the expiration date for continuing review.

- **SERIOUS ADVERSE EVENT REPORTING**: All serious problems having to do with subject safety must be reported to the National Health Sciences Research Committee within 10 working days using standard forms obtainable from the NHSRC Secretariat.

- **MODIFICATIONS**: Prior NHSRC approval using standard forms obtainable from the NHSRC Secretariat is required before implementing any changes in the Protocol (including changes in the consent documents). You may not use any other consent documents besides those approved by the NHSRC.

- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the NHSRC using standard forms obtainable from the NHSRC Secretariat.

- **QUESTIONS**: Please contact the NHSRC on Telephone No. (01) 789314, 08588957 or by e-mail on doccentre@malawi.net

- **Other**: Please be reminded to send in copies of your final research results for our records as well as for the Health Research Database.

Kind regards from the NHSRC Secretariat.

FOR CHAIRMAN, NATIONAL HEALTH SCIENCES RESEARCH COMMITTEE

PROMOTING THE ETHICAL CONDUCT OF RESEARCH

Executive Committee: Dr C. Mwassambwa (Chairman), Prof. J. Mijiwo Bengo (Vice Chairperson)
Registered with the USA Office for Human Research Protections (OHRP) as an International IRB
(IRB Number IRB00003905  FWA00005976)
Marlene Galimoto  
DISTMS  
Lilongwe

Dear Madam,

RE: PROTOCOL # 662: ‘IMPLEMENTATION AND USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) TO IMPROVE MATERNAL HEALTH SERVICES’

Thank you for the above titled proposal that you submitted to the National Health Sciences Research Committee (NHSRC) for review. Please be advised that the NHSRC has reviewed and approved your application for extension and modification of the above titled study.

- **APPROVAL NUMBER**: 662
- The above details should be used on all correspondences, consent forms and documents as appropriate.
- **APPROVAL DATE**: 21/06/2011
- **EXPIRATION DATE**: This approval expires on 20/06/2012. After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the NHSRC Secretariat should be submitted one month before the expiration date for continuing review.
- **SERIOUS ADVERSE EVENT REPORTING**: All serious problems having to do with subject safety must be reported to the NHSRC within 10 working days using standard forms obtainable from the NHSRC Secretariat.
- **MODIFICATIONS**: Prior NHSRC approval using forms obtainable from the NHSRC Secretariat is required before implementing any changes in the protocol (including changes in the consent documents). You may not use any other consent documents besides those approved by the NHSRC.
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the NHSRC using standard forms obtainable from the NHSRC Secretariat.
- **QUESTIONS**: Please contact the NHSRC on telephone number +265 1 726 422 or email address mouldocentre@gmail.com.
- **OTHER**: Please be reminded to send in copies of your final research results for our records (Health Research Database).

Kind regards from the NHSRC Secretariat.

For, **CHAIRPERSON, NATIONAL HEALTH SCIENCES RESEARCH COMMITTEE**
Promoting Scientific and Ethical Conduct of Research in Malawi

Executive Committee: Dr C. Mwansambo (Chairperson), Prof. J.M. Bengo (Vice-Chairperson)
Registered with the USA Office for Human Research Protections (OHRP) as an International IRB
IRB Number IRB00003995 FWA00005976
Appendix 8a: English Consent form

Consent Form for Adult Participation

Title of Study: Implementation & Use of Information & Communication Technologies (ICT) to improve Maternal Health Services  
Principal Investigator: Marlen Stacey Gali moto  
Email Address: marlensg@ifi.uio.no.  
Telephone number: 0999 588 635

What are some general things you should know about this research?  
You are being asked to take part in a qualitative research study. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study, for any reason, without penalty.  
Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about being in this study. You may ask any questions you have about this study at any time.

What is the purpose of this research?  
The purpose of this study is to explore ways for using ICT in the area of Maternal health to improve management, accessibility, communication and use of health-related information among health workers involved in Maternal health service delivery.

How many people will take part in this study?  
The study intends to interview and observe facility and community health workers who are involved in providing Maternal health services in facilities i.e. nurses, clinicians, medical assistants and health surveillance assistants. Additionally coordinators/managers of Maternal health programmes at the district and national levels will also be interviewed as part of this study.

What is your part in this study?  
If you decide to be in this study, you will first be asked to participate in one initial interview that will last for not more than one hour. Later I would like to observe work routines in your work place and based on observations I might have more questions at a later date, or (if appropriate) during observation. This will be done to assist in understanding your work in order to clearly identify your information and communication needs.

Based on the identified requirements, a system will be proposed and developed. The system will be implemented in two selected health facilities and if one of them is the facility where you are working, you will be involved in testing of the system to ensure that the system meets your needs.  
After using the system for at least 6 months, you will be interviewed and observed in your work to evaluate the effect of the system in the performance of your work. The focus will be on the impact of the system on Maternal health data quality, data accessibility and communication and the effects on the service provision itself.

What are the possible benefits from being part of this study?  
You will have the opportunity to share your thoughts about your work related to the information system and to improve the system. You will not be paid to participate in this study. There are no costs for participating in the study other than your time spent.

Although you may not experience any direct benefits, your participation may help to improve the management of Maternal health information in your work place in future. However, there is a possibility that you may receive no direct benefit.

What are the possible risks or discomforts involved from being in this study?  
The main risk is that you may feel uncomfortable answering some of the questions during interviews. You may be embarrassed or afraid to disclose information about your work relations or colleagues.
You may refuse to answer any question that you do not want to answer. You can also stop participation at any time. You should report any problems to the researcher.

**How will your privacy be protected?**

Names *will not* be attached to interviews and the data will be kept confidential. To protect your privacy, all of the information you provide will be stored only with an identification code, not with your name. Participants will not be identified in any report or publication about this study. The notes and audio recordings containing your interview responses will be accessible to only me and all the data will be destroyed when the study is over.

**What if you have questions about this research?**

You have the right to ask, and be answered, any questions you may have about this research. If you have questions, or concerns, you should contact the researcher listed on the first page of this form.

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**Written Consent Verification**

I have read the information above and have agreed to participate in this study.

________________________________________  __________________
Signature of Person Giving Consent          Date

________________________________________
Printed Name of Person Giving Consent
Appendix 8b: Chichewa Consent Form

KALATA YA CHILOLEZO YA MUNTHU WAMKULU OLOWA MU KAFUKUFUKU

Dzina La Kafukufuku: Kagwiritsidwe ka zida zamakono zosungira ndi kufalitsira nkhani pogwira ntchito yokhudzana ndi uchembere.
Wamkulu wa Kafukufuku: Marlen Stacey Galimoto
Lamya yopezera Wamkulu wa Kafukufuku: 0999 588 635

Ndichiyani chimene muyenera kudziwa za kafukufuku amenyu?
Inu muli kupemphedwa kutenganawo mbali mukafukufuku ofuna kudziwa mmene zida zamakono zosungira ndi kufalitsira nkhani zingathandize pogwira ntchito yokhudzana ndi uchembere. Kulowa newo mukafukufuku amenyu ndi kwakufuna kwanu. Inu muli omasuka kukana kulowa mukafukufuku, mkhozanso kunena kuti simupitilira ndi kafukufukuyo muli m’katikati popanda mulandu utionse kapenanso kulipirapo chirichonse.


Kodi kafukufuku amenyu ndiwa chiyanji?
Kafukufuyu akuchitika pofuna kudziwa mmene zida zamakono zosungira ndi kufalitsira nkhani zingathandize pogwira ntchito yokhudzana ndi uchembere.

Kodi ndi anthu angati amene alowa nawo mu kafukufuku amenyu?
Kafukufuyu amenyu achitika m’maboma anayi muzidziwa mwe ndipo anthu osiyanasita ogwira ntchito yokhudzana ndi uchembere adzapemphedwa kuti atenge nawo mbali mukafukufuku amenyu.

Chichitike nchiyani mukalowa nawo mu’mkafukufukuyu?
Ngati mutabvomere kutenga newo mbali mukafukufuku amenyu tidzacheza nanu koyamba kosapitilira hora imodzi. Kenako tidzafuna kuona kagwildwe ka ntchito ndipo tidzafunanso kuchese nanu tsiku lina. Izi zidzachitidwa pofuna kudziwa nkhani zomwe zimakulondidza pogwira ntchito ya uchembere komanso kulumikizana ndi ogwira ntchito ena komwe kumakulondidza.

Podziwa zimenezi zida zamakono zosungira ndi kufalitsira nkhani zizaiyidwa muzipatala ziwir zosankhidwa pofuna kuyesa ngati zingathandize pogwira ntchito anu ya uchembere. Ngati ziptalazo zidzakhala komwe mukugwira inuko, muzapemphedwa kuti inu muziyese pogwira ntchito anu ya uchembere kuti muone ngati zili zokuthandizani. Chonco, potsatira, tidzacheza nanunso ndi kuonanso kagwiridwe kanu ka ntchito pofuna kufuna kudziwa ngati zidazo zikukuthandizani pa ntchito anu.

Kodi inu mungkininde bwanji ndi kafukufuku amenyu?
Inu mukhala ndi mwai okamba momasuka ndi mozama za kagwilidwe ka ntchito yokhudzana ndi uchembere makama kataleredwe, kasungidwe ndi kafalitsidwe ka nkhani. Komanso mukhala ndi mwai okamba momasuka njira zotukulira ntchito imenyi.

Ngakhale simungaone phindu kwa inu, koma potenga mbali mukafukufuku amenyu mukhoza kuthandiza kuti zinthu zitukute mtsogolo m’Boma lanu ndi dziko la Malawi. Musayembekezere kulipidwa kapena kulandirapo chirichonse pokhala gawo limodzi la kafukufuku. Inu simulipirira kanthu pokhala mu kafukufuku koma chimene tiliri kupempha ndi nthawi anu kuti ticheze mofatsa.
Kodi ndi zoopysa ziti zimene mungakumane nazo mkafukufukuyu?

Chinsinsi chidzasungidwa bwanji?
Zolembedwa ndi zojambulidwa zonse sizidzakhala ndi dzina lanu, izi zidzakhala ndi manambala ngati zizindikiro. Zotsatira za kafukufukuyu sizidzatchulapo dzina la munthu wina aliyense.

Makope ndi matepi amene agwiritsidwe ntchito mu nthawi ya kafukufukuyi adzaonogedwa pomaliza pa kafukufuku. Kupatulapo mkulu wa kafukufu ndi omuthadizira palibe wina amene adzadziwa zomwe inu mwanenapo mukafukufuyu.

Ngati muli ndi mafunso pa kafukufukuyu
Muli ndi ufulu ofunsa ndi kuyankhidwa china chili chonse chokhudzana ndi kafukufukuyu. Ngati mungakumbukire mafunso ena ife titachoka khalani omasuka kufunsa kwa anthu amene talemba kumayambiri kwa chikalata chino.

Ine ndabvomera kulowa nawa mu’mkafukufuyu

_________________________________________ __________________
Dzina ya Munthu wabvomera kulowa kafukufuku Tsiku

_________________________________________
Chizindikiro cha Munthu wabvomera kulowa kafukufuku
Appendix 9a: Interview and observation guide during initial diagnosing

This Interview guide will be used during the diagnosis phase of the research to collect data from Maternal health workers at the facilities, in the community and programme coordinators/managers so as to understand their information needs.

Interviewer: ............................. Meeting Place: ......................... Date: ............................ Start Time: ................. End: .............. Language: ...................... Attended by: ..............................
Interviewee:
Name: ........................................ Position: .................................
Duration in current position: ..............................................................
Years of Service: ........................................................................
Highest Qualification: .......................................Date Obtained: ...........................
Institution: ..................................................................................

QUESTIONS

1. What Maternal health care services do you provide?
2. What are the work routines for providing this service
3. Do you have any guidelines or procedure manuals for provision of care or services?
4. What data/information is collected during delivery of service?
5. How is the data collected?
6. How is the data used?
7. How is the data useful to you?
8. How is the data useful to others?
9. Is it easy for you to use the data? Please explain.
10. Is it easy for you to find or access the data?
11. What client data do you feel you need to know to be able to provide a good service to a client?
   a. How do you obtain such information?
12. What data is missing in the current data collection tools that you feel is necessary?
13. What is your opinion of the data collection tools in use?
14. Who do you report the data to?
   a. How often do you report the data?
   b. Are you able to produce the reports on time?
   c. What Challenges/problems do you face in relation to producing reports?
15. What problems/challenges do you face in your work in relation to:
   a. collecting/recording patient data
   b. Analysing the data
   c. Aggregating the data?
   d. Reporting the data
   e. Using the data?
16. When/ For what cases is a patient referred to another hospital?
17. What are the procedures/protocol for referring a patient?
18. What information is provided when referring a patient/client?
19. What mechanisms are in place for communicating with the referral hospital?
20. What feedback, if any, is provided by the referral hospital?
21. Are there any community health workers providing Maternal health services?
   a. Who are these?
   b. What services are they providing?
22. How do you coordinate your activities with these community health workers?
a. How often do you communicate with the CHWs?
b. How do you communicate with the CHWs?
c. What problems do you face in trying to communicate with the CHWs?

Additional Questions For Community Health Workers

1. Are there other CHW providing Maternal health services?
2. Do you work in collaboration with them?
   a. In what ways?
3. How often do you communicate with these other CHW?
   a. How do you communicate with them?
   b. What problems do you face in trying to communicate with them?
4. How often do you communicate with the health centre/hospital?
   a. How do you communicate with them?
   b. What problems do you face in communication?
5. What tools are used to record data during delivery of (Maternal) health care services in the community?
6. What is the purpose of collecting this data (use of data)?
7. What reports do you produce (If any)?

For Programme Coordinators/ Managers at District and National level

1. What are your responsibilities as coordinator of the programme?
2. What health data do you need to perform your duties?
3. Where do you find the data required?
4. Is the data easily accessible for you when you need it?
   a. If not, how can it be improved?
5. What reports do you produce based on the health data?
6. What tools do you use to prepare the reports?
7. Who are the programme stakeholders?
8. Do you share or communicate programme data or reports with stakeholders?
   a. If so, how is this done?
Appendix 9b: Interview and observation guide for baseline data collection

**BASELINE DATA COLLECTION- Implementation of Electronic Information System in Health Centres**

**Interviewer:** .......................................................... Meeting Place: ................................. Date: .................................


**Interviewee:**

Name: .......................................................... Position: ..........................................................

Age:......................................................

Duration in current Position:.........................

Work History/ Years of Service:..........................................................

Highest Professional Qualification:..........................Date Obtained:.........................

Institution: ..........................................................

1. **WORK PRACTICE ASSESSMENT**

   This aims to collect qualitative and quantitative data on the current work practices surrounding Antenatal care service delivery.

1.1 **SERVICE DELIVERY- WORK FLOW, PATIENT FLOW & ENCOUNTERS**

   1. Review the ANC activity diagram is still the same?
   2. How do you decide on topics to cover for Health education for that day?
   3. Are there any guidelines/standard protocols for ANC service delivery?
      a. Do you have a copy of the standards/guidelines? Get copy
      b. Do you ever refer to these standards? WHEN/For what?
      c. Are you able to adhere to these protocols? And if not why?
   4. What problems do you face in delivery of Antenatal care?
   5. What additional training do you think you need to be able to provide a good service?

1.2 **DATA COLLECTION**

   1. What information about the client do you feel you need to know to be able to provide Antenatal care to a client?
   2. How do you obtain this information?
   3. What problems do you have in obtaining this information?
   4. What information do you record about the patient and where?
   5. What problems do you have in recording this information?
   6. What information do you think is missing in the current data collection tools that you feel is necessary to be able to provide a good service/care to the client?
   7. Did you receive any training on using the tools (health passports, registers and reports)?
      a. Are there any guidelines/protocols on how to fill the ANC registers/health passport for ANC
   8. What is your opinion of the data collection tools in use?
      a. When assessing the client in trying to identify risk factors in clients - How do the tools enable/hinder this?

1.3 **DATA REPORTING**

   1. What reports do you produce?
   2. How often do you produce the reports?
   3. How long does it take you to produce the reports?
   4. What problems do you have in producing the reports?
   5. Who do you send the reports to?
      a. For what purpose do you think they use the report?
   6. How do you send the reports?
   7. What problems do you have in sending the reports?
   8. How do you use the data from the registers/reports as an individual or a facility?
2. **COMPETENCY ASSESSMENT**

This aims to assess the competency levels of healthcare workers in ICT and service delivery.

2.1 **ICT COMPETENCY**

2.1.1 **COMPUTERS**

1. Have you used a computer before? If Yes,
   i. For what?
   ii. What packages did/do you use?
   iii. How long did/have you been using those packages?
   iv. Have you attended any computer course?
   v. Do you own a computer?

2. Have you used an electronic medical record system before (this or any other)? If Yes,
   vi. When do you use it?
   vii. How do you use? / For what?
   viii. How long have you been using it?
   ix. Did you attend any training on this?
   x. *Observe interviewee using the computer/system*

2.1.2 **MOBILE PHONES**

1. Do you own a mobile phone? / Have you ever used a mobile phone?
2. For how long have you been using one?
3. What applications do you use?

3. **OBSERVATIONS**

1. How long does it take for the nurse to attend to ANC clients, total number that day and hours?
2. How long does it take the provider to retrieve a client’s record in the register i.e. time for searching a patient?
3. How does the provider interact with the client during consultation and how much time does it take (i.e. the interaction at each point)?
4. How long does it take for the patient, i.e. waiting time and total length of stay at the hospital? Follow one patient through and time it.
5. To what extent does the provider adhere to standard protocols and if non-adherence, find out why.
6. How long does it take to record patient information in the various tools at various points?
7. Go through the registers and health passports and check how the information is captured. Check for gaps/errors.
8. How are the monthly reports produced and how long does it take? Be there during report generation.
9. Assess timeliness of the reports - producing them and sending them to DHO.
10. Assess accuracy/completeness/correctness of the reports produced
Appendix 9c: Interview and observation guide during evaluation

EVALUATION OBJECTIVE
This aims to evaluate the effect of the Antenatal Care Electronic Medical Record system on Antenatal Care service delivery at the health centre.

INTERVIEW GUIDE – health personnel
Date: ........................................... Start Time: ......................... End Time: .........................
Interviewee:
Name:..............................................................................................
Position: ..............................................................................................
Age:.................................................................................................
Duration in current Position.................................
Work History/ Years of Service:...............................................................
Highest Professional Qualification........................................Date Obtained...........

1. SERVICE DELIVERY
   1. What is the patient flow for ANC with the system in place?
   2. What was your work in relation to ANC before the system was in place?
   3. What is your work now in relation to ANC with the system in place?
   4. For what activities do you use the system?
   5. How has the system affected your work in terms of ANC service delivery?
      a. Has it improved in any way?
      b. Has it deteriorated in any way?
      c. How does the system enable/hinder you in:
         i. Identifying risk factors in clients (i.e. High risk clients)?
         ii. Providing preventative care.
      d. Is the work quicker/the same/slower now with the system than it was before without the system?
   6. In your opinion, what is the most useful feature of the system?
   7. What are other advantages of using the system?
   8. What problems do you face in using the system?
   9. What are the disadvantages of using the system?
   10. In your opinion, what features do you think are less useful?
   11. How has the system affected your knowledge on ANC service delivery? Explain
      a. Has this affected your work elsewhere/ in general?
   12. In your opinion, how can the system be improved to better support ANC service delivery?

2. DATA COLLECTION & REPORTING
   1. What information have you been entering in the system?
   2. What problems do you have in entering information in the system?
   3. What information do you (want to) retrieve from the system?
   4. What problems do you have in getting this information?
   5. In your opinion, to what extent is the information in the system reliable?
   6. What information do you think is missing in the system?
   7. How well is the system working with other tools (Health passport and registers)? Explain
   8. Do you use the reports (cohort and dashboard statistics) from the system?
      a. If so, when and how?

3. USER SUPPORT
   1. What do you do when you encounter any problems with the system?
4. OBSERVATION GUIDE
   1. How long does it take for the nurse to attend to ANC clients, total number that day and hours?
   2. How long does it take the provider to retrieve a client’s record in the system i.e. time for searching a patient?
   3. How does the provider interact with the client during consultation and how much time does it take (i.e. the interaction at each point)?
   4. To what extent does the provider adhere to standard protocols and if non-adherence, find out why.
   5. How long does it take to record patient information in the various tools at various points?
   6. Check the database to assess completeness of the data in the system.

5. ANC CLIENTS’ INTERVIEW GUIDE
   1. Name
   2. ID no./ Registration number
   3. Education level
   4. What do you know about the computer system?
   5. Have you been here for previous pregnancies? If so
      a. How do you compare service delivery then and now?
   6. What is your opinion of the computer system in terms of:
      a. Efficiency/delays in service delivery?
      b. Interaction with the nurse & others?
   7. Check the clients HP and check ANC assessment that was done
      a. Any missing data?
      b. If there is a danger sign did the nurse say anything about it?
      c. Can the client read/understand the information in the health passport in general?